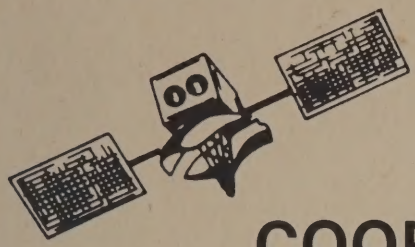


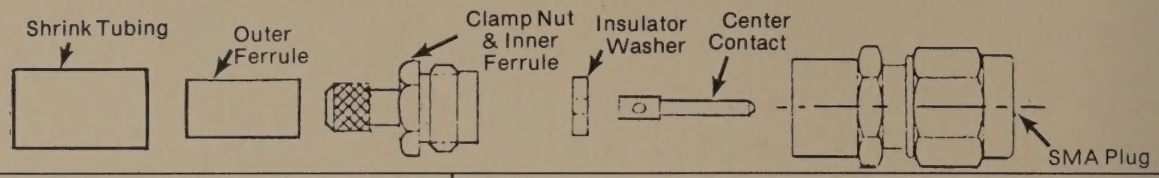
COOP'S SATELLITE OPERATIONS MANUAL

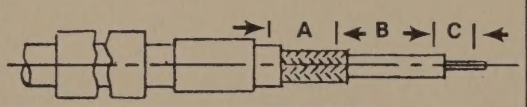
The 'Keep-It-By-Your-Receiver' guide to where to tune for what, how to spot TVRO/ARO reception system problems before they become big headaches, how to make the new terminal function best, quickest, with the least amount of 'down time', and, a thorough background on the domestic (DOMSAT) and international (INTELSAT, MOLNIYA, GHORIZONT) satellite systems in use in the world today.

Reprinted from original 1980 master by COOP'S TECHNOLOGY DIGEST, P.O. Box 330, Mangonui, Far North New Zealand; Copyright 1980 and 1994 by Robert B. Cooper

PRICE: $30 per copy

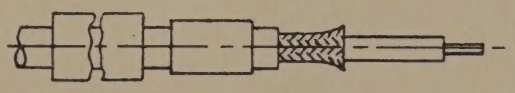
ASSEMBLY PROCEDURE FOR CRIMP TYPE SMA CONN. CABLE ACCOMODATION
RG-188A/U,-316/U,-174/U,-179B/U & -187A/U



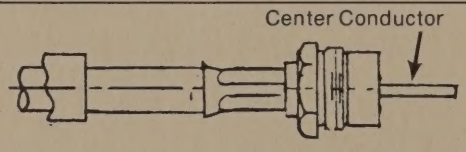


Connector	A	B	C
901-9601-3	.270	.230	.120
901-9601-3SF	.270	.230	.120

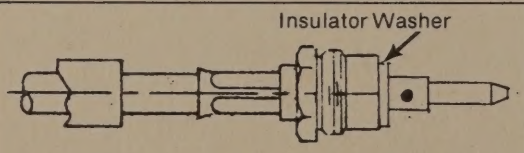
Slide heat shrink tubing and outer ferrule onto cable. Strip cable jacket, braid and dielectric to dimensions shown. All cuts are to be sharp and square. Important: Do not nick braid, dielectric or center conductor when cutting. Tin center conductor. Avoid excessive heat to prevent swelling of cable dielectric.



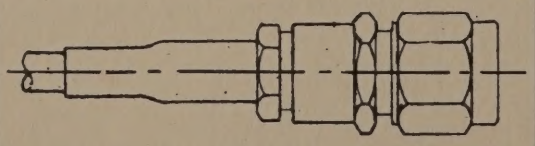
Flare end of cable braid slightly as shown to facilitate insertion onto inner ferrule.
Important: Do not comb out braid.



Slide clamp nut and inner ferrule under braid until cable dielectric is flush with front of inner ferrule. Slide outer ferrule in place and crimp with Amphenol tool No 227-944 and die set 227-1221-03 cavity "A" (M22520/5-03 Closure A.)



Place insulator washer on cable center conductor and bottom against inner ferrule body. Contact must butt firmly against insulator washer while soldering.



Screw ferrule-contact assembly into body and tighten to 20-25 in./lbs. torque. Slide heat shrink tubing over ferrule, up against clamp nut and shrink by applying heat.

COOP'S SATELLITE OPERATIONS MANUAL

...A Manual, yea...a complete guidebook and reference book to what it is that is happening in the satellite operations world today. A thorough study on what satellites are doing what, where, plus numerous 'chapters' on proven, down-to-earth home satellite reception system installation and trouble shooting techniques.

TOPIC **PAGE NUMBER**

The Twist..... 2
Rotating The Feed..... 3
Aligning The Feed With The Satellite..... 4
Powering The LNA (safely!)..... 7
When It Doesn't Work (and you need help)..... 9
C + N/N and SNR 12
RCA SATCOM FI Coverage Patterns.....15
Typical DOMSAT Satellite Operating Parameters.....16
Re-Broadcasting - Thru Air Re-Distribution.....17
Sub-Carriers On The Birds.....21
Narrow Band Voice/Data Services (Look/Don't Touch).....24
SATCOM F2 TV Services.....32
Those International Satellites.....34
Molniya Locating System.....42
Waveguide To Coax Adapter.....49
Terrestrial Interference.....52
Video Lowpass Filter.....52

THE COVER - Bob Cooper and two of his 'toys'; the original 20 foot 'monster-dish' he installed in September of 1977, thereby making his family the first in the United States to have private (home) satellite service, and a smaller 11 foot dish antenna which he currently utilizes to bring in reception from Russia's Molniya inclined-orbit satellites. Coop has been 'rat-holing' his observations plus those of others over the years and in this first-for-Coop Manual format he tells you things you need to know but cannot find anyplace else!

THIS MANUAL has been produced and is being distributed by Satellite Television Technology, P. O. Box 2476, Napa, CA 94558. The price per copy is $30. Material in this Manual is believed to be current and yes, accurate, at the time of publication. Material found here which relates to satellite operations is likely to change however and those changes will be reported through the pages of **'Coop's Satellite Digest'** (CSD) monthly as they occur.

COPYING THIS MANUAL - This Manual is copyrighted 1980 © by Bob Cooper, Jr. and by Satellite Television Technology. This simply means that under US copyright laws it is something of a federal offense should you decide that you wish to share some or all of the contents with others; either for free or for some charge you may unwisely decide to make. Under international copyright treaties this copyright 'protection' also extends to Canada and throughout the world where the US is party to signatory agreements relating to copyright protection. The fact of the matter is that people do copy things everyday, often out of ignorance, more often out of little fear of being apprehended for such a heinous crime. Others, mindful of the copyright laws, prefer to plagarize material from reference sources such as this one; in the satellite TV field a firm in Florida regularly awaits the introduction of each new STT manual so that they can in turn revise their own literature by lifting segments from our innovative reports. Regretfully, for them, they always seem to either do it improperly (one would think that simple copying would present no mental challenges!) or manage to lift data that has been planted by us primarily to allow us to spot 'lifted' material. Such is life...some of us innovate and others are destined to go through life copying. We thank you for making this Manual a part of your own library and by your support in purchasing (**not** copying) this Manual you are assured that we will continue to share material like this with you in future Manuals!

CONTACTING STT: For additional copies of this Manual ($30 each) or for a complete listing of seven different Manuals offered to the low-cost TVRO enthusiast by STT, or for subscription information to **Coop's Satellite Digest** you may contact STT (Satellite Television Technology) at P. O. Box G, Arcadia, OK 73007 USA (405/396-2574). **Sorry** - your chances of getting through to Coop on the telephone are not good and if you have questions or wish additional information, we suggest that you write him in care of STT. Thank you.

THE TWIST

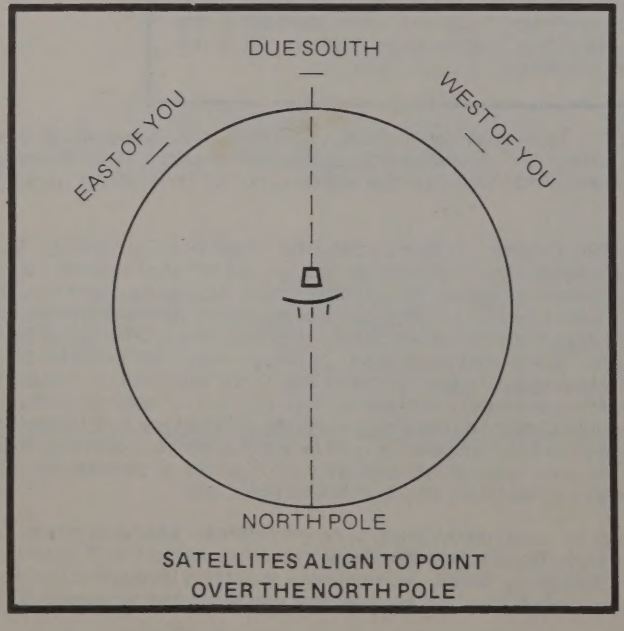
We speak very glibly in this field of antenna polarization; the 'horizontal channels' and the 'vertical channels'. The truth is that for very few of us are the horizontal signals ever horizontal or the vertical signals ever vertical. Understanding how this really works can save you lots of grief with your installation.

The satellite sits out there in space directly above the equator; in a box that typically measures (for DOMSAT birds) around 70 miles east and west, 50 miles north by south and as little as 20 miles up and down. Flight controllers and computers monitor the satellite's location by 'ranging' on it from two or more different terrestrial locations, and then feeding the apparent measured coordinates from each location into a computer with sufficent capacity to 'solve' the actual location equation. When the bird moves close to one of the boundaries of this mythical box the computer tells the satellite controllers it is time to fire a thruster rocket or a bay of rockets to nudge the satellite back towards the opposite side of the box. The thruster rockets have a very light 'touch'; typically 1/10th pound thrust when fired and they measure the firing time in microseconds. With virtually no drag or friction it doesn't take much of a nudge to get the bird to 'move over'.

NOW - as the satellite sits in the middle of its 'box' it has its 'attitude' adjusted. That is, ground controllers attempt to make it 'square' with the point of reference all geostationary satellites utilize; **an imaginary point in the sky directly above the north pole.** When the satellite is aligned to this spot, the polarization of the downlink (transmitting) and uplink (receiving) antennas is squarely linear. In the case of **ANIK** and **WESTAR** 'linear' means the waves leaving the bird are **horizontal.** Or in the case of **SATCOM** and **COMSTAR** the wavefront energy is **either** horzontal or vertical (depending upon the channel grouping).

Now comes the tough part. The satellite's polarization is to the true north. For example, if the satellite sits at 119 degrees west longitude (as SATCOM F2 does), the polarization will be truly horizontal (transponders 2, 4, 6 etc. thorough 24 on F2) and truly vertical (transponders 1, 3, 5 etc. through 23 on F2) **only if you are located on that same 119 degree west longitude line** yourself; and there are no unusual things happening to the wave front on its way back down to you.

Now let's say you are **east of** 119 degrees west; perhaps 90 degrees west. From your vantage point the horizontal signal leaving F2 is no longer horizontal! In fact it is 'skewed' (as in twisted) so that it cocks back counterclockwise from true horizontal (the same thing happens to the vertical wavefronts from F2). OR - if you were **west of** 119 degrees, the wave would skew in the opposite direction; clockwise away from the true horizontal format. In other words, **only a satellite due south of you** will arrive at your location with its polarization **the same as it left the bird.** East it twists counterclockwise and west it twists clockwise.



SATELLITES ALIGN TO POINT OVER THE NORTH POLE

The signal doesn't really twist you understand; it is just that you sit off at an 'angle' looking back towards a linear wavefront; it is both above you and off at an angle. If you have trouble visualizing this take a short stick such as from a popsicle and mount it horizontal on a wall. Now walk away from it straight ahead, turn around and look back. Sure enough, it is still horizontal. Now walk off at an angle and look back. Is it still horizontal with respect your 'skewed' viewing angle? No it is not.

In the real world then you have to make an adjustment with your probe-inserted-in-feedhorn antenna.If you are only looking at one satellite, you have to skew or twist the feedhorn one time to optimize your own probe polarization to match the 'offset' of your location. But if you are going to move your dish aroung from satellite to satellite, as you start off with a western satellite (such as FI) you will start off with the horn cocked ahead by some clockwise amount off of true linear and as you move east through the various satellites to end up at COMSTAR D3 at 87 degrees you'll probably end up with the feed antenna cocked back in the opposite direction.

Now the real confusion. Everything you just read is 180 degrees wrong!

How's that? Well, if you are employing a Cassergrain feed, actually it is correct. Very few private terminals employ a Cassegrain type feed (this type collects the satellite energy on the dish surface, focuses the energy to a small 'hub cap' shaped sub-reflector mounted out at the dish focus point, and then re-focuses all of this energy back to the actual antenna feed which mounts at the center of the dish where it protrudes through a hole.). But for the rest of us, utilizing a 'prime focus' feed where the LNA + feedhorn and probe pickup instrument are located out in front of the dish, we have to **reverse** everything you just learned and understood.

When the satellite signal reflects from the parabolic dish, the dish surface actually turns the signal around. **What was left becomes right** and vice versa. So if the wavefront was skewed clockwise (for a signal coming from the west of your longitude). after it bounces from the reflector surface and focuses towards the prime focus mounted feed now it is skewed counterclockwise! The opposite is true for signals from east of you.

So here's the operating data you need:

1) **When you look at a satellite** more or less (+/- 10 degrees) due south of you, you don't have to worry about skewing the feed probe; what leaves the satellite linear vertical will arrive to you linear vertical, or nearly so, **most of the time.** Ditto linear horizontal.

2) **When the satellite is east** of you by more than 10 degrees, you start to have enough skew that you will have to adjust the feedhorn probe off of linear whatever to match the incoming wavefront. **For eastern signals** received on a **prime focus** feed dish, this amounts to a **clockwise shift.**

3) **And when the satellite is west** of you (as most are for most people in North America) the twist is **counterclockwise.**

Is there more to it than that? Yes...and no.

First of all, most probe feeds are very broad in their acceptance of moderately off-polarization signals. In fact the recommended way to adjust a feed for proper alignment is to not select a signal you want but rather to select a cross-polarized signal you do not want and then adjust your feed polarization for a 'null'. Here's how that works:

1) Let's say you elect to adjust your feed on SATCOM. Rather than attempting to 'peak' it on a signal you are watching. by adjusting the polarization for maximum signal. because the probe's polarization response is so **broad** in adjustment you instead select a transponder that is polarized in the **opposite** polarization and **adjust** for **maximun rejection.**

2)Take transponder 3 for example on F1. By setting your receiver to 3 you can rotate the feed until there is no sign of transponder 3's signal. You can do this because transponder 4 is empty (actually broken) and as you rotate on 3 (especially if you tune high on 3 about half way to 4 with your receiver) you will be in no danger of tuning out of one and into another.

3)By aligning the feed for **maximun rejection of** 3 (vertical) you are now assured that you simulaneously have **maximum pickup** (i.e. peak performance) on horizontal polarized signals. The same thing can be repeated on 20 (by tuning the receiver down towards 19) for maximum rejection of the horizontals (and maximum alignment with the verticals).

This whole technique is called aligning for 'cross-pole'; a fancy phrase that means you **align for maximun signal null** not signal peak. It works because the null is very sharp (typically under ten degrees) while the peak is typically very broad (as much as 40 degrees).

Is there more to this? Yes, one thing. During travel from the bird to you there is slight opportunity for the polarization to shift on its own. It can happen either of two places. The first after leaving the bird is as the signal passas through the earth's fairly complicated magnetic field. Here something called **Faraday Faraday Rotation** can cause the signal to twist by up to (+ /-) 3 degrees. As you might guess, you probably could not see + /- 3 degrees of shift with your antenna feed, even in the null position. But, such twisting can be cumulative when you also consider the second potential area for twist; the earth's atmosphere.

For most locations and for most of the time the lower atmosphere does not cause any 'problems' to the incoming signal. Here are the exceptions:

1)For virtually any 'look angle' (i.e. elevation angle from your location to the bird), **a very heavy rain storm** is capable (based upon extensive measurements by NASA and RCA) of 'twisting' or 'skewing' the polarization by much as + /- 15 degrees. This is an extreme of course, but it can and has happened at 4 GHz. If this polarization twist happens when there is severe (i.e. 3 degree) Faraday Rotation, the cumulative total of the two may be seen and in fact measured at a receive site.

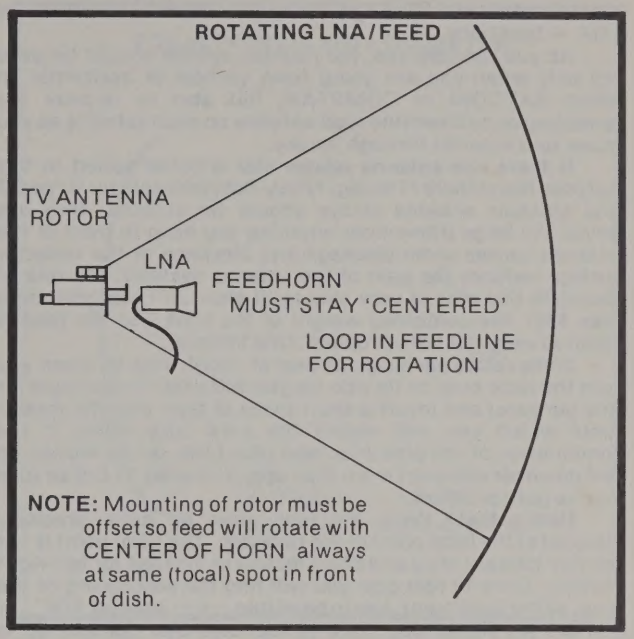
2)**For low look angles** (i.e. those in the **under** 15 degree area) the signal is starting to travel through a rather substantial chunk of the lower atmosphere. The more lower atmosphere it travels through (i.e. the weather producing layer closest to ground) the greater the opportunity for the atmosphere to exert some influence on the signal. It is possible for either heavy rain, or a condition that occurs in clear, stable weather (a temperature inversion) to distort the polarization of the signal. It could amount to + /- 15 degrees and perhaps more when the look angle is low **and** the receiving terminal is located in a semi-tropical or tropical climate area.

All of this assumes the bird is itself maintaining the proper attitude at all times. Ground controllers claim they never allow the satellite to get 'out of kilter' by more than + /- 2 degrees from its reference due-north alignment position. However there have been brief periods of a few minutes to several hours when a satellite has been known to 'get away' from controllers and start twisting on its own.

ROTATING THE FEED

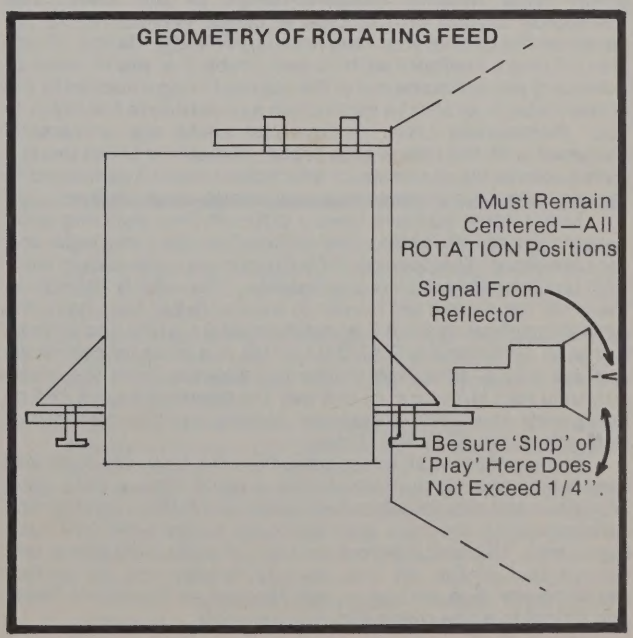
Most people interested in private terminals are well aware that if you mount your feed antenna on a piece of pipe or mast and then insert that pipe or mast into a common, everyday TV antenna rotator which in mounted on its side, you have a handy-dandy way to rotate the antenna feed system from vertical to horizontal and then back to vertical. Such a system was first proposed and detailed in **CATJ** Magazine for February 1979 after Coop's STT terminal was adapted for this use in the fall of 1978. Since that time virtually every private terminal offered has been so equipped.

The system is very simple as you see here. The mounting plate for the LNA which mormally provides some method of


ROTATING LNA/FEED
TV ANTENNA ROTOR
LNA
FEEDHORN MUST STAY 'CENTERED'
LOOP IN FEEDLINE FOR ROTATION
NOTE: Mounting of rotor must be offset so feed will rotate with CENTER OF HORN always at same (focal) spot in front of dish.

mechanical (i.e. hand) movement of the feed + LNA package is replaced with the motor drive of the TV antenna rotator. If you are adapting an existing prime focus feed to this application, you will have to evaluate the physical space required to stick the antenna rotator in 'behind' the LNA + feed as shown here. The antenna rotator moves at just about the ideal speed; typically one complete rotation in 30 seconds to one minute. Plus it comes with a handy control box which while normally calibrated in 360 degrees can be recalibrated or marked in 'vertical' and 'horizontal' indicating spots.

Most TV antenna rotators come out of the box aligned against a 'stop' position; perhaps true north [or south]. Before installing the rotor motor hook up the control box and rotate the motor 180 degrees so that you are no longer against a 'stop' but rather are 180 in either direction from a stop. Now when you install the rotor motor and put the LNA + feedhorn on the rotating pipe you will have 180 degrees of rotation in both directions to move. This will allow the rotor motor to slip some


GEOMETRY OF ROTATING FEED
Must Remain Centered—All ROTATION Positions
Signal From Reflector
Be sure 'Slop' or 'Play' Here Does Not Exceed 1/4''.

in use without your having to either re-mount or re-adjust the LNA + feed horn.

As you can now see, the rotation system should be used not only when you are going from vertical or horizontal on either SATCOM or COMSTAR, but also to re-peak (by re-nulling as outlined)the feed antenna on each satellite as you move your antenna through the sky.

Is there one antenna rotator that is better suited to this purpose than others?The big, heavy-duty jobs sold for large CB and amateur antenna arrays should be avoided; they are physically large (remember anything you hang in front of the antenna causes some blockage and blockage of the reflector surface reduces the gain of the antenna system). My rule of thumb in this area is very simple; it shouldn't cost you more than $30! The combined weight of the LNA and the feed is small so weight is not a problem. One thing is.

Some rotors have a great deal of 'slop'; that is, when you turn the rotor over on its side (as you will when mounting it for this purpose) and insert a short piece of pipe into the rotator (onto which you will mount the LNA plus horn) if the combination of the pipe plus feed plus LNA can be moved up and down (or sideway) more than approximately 1/4 of an inch you've got a problem.

How's that? Well, the feed must be quite precisely situated at the focal point of the reflector. The focal point is not terribly tolerant of up and down motion in the feed (or left-right motion). On a 10 foot dish you will find the positioning of the feed, at the focal point, has to be within +/- around 1/4'' or you can see signal loss. On a 15 foot dish that tightens up to +/- 1/10th of an inch. If the 'slop' in the rotor is such that the weight of the LNA plus feed pulls the feed assembly **down** towards the ground by more than 1/4th of an inch as the rotor hangs there on its side you could well end up with the feed 'hanging out of the focal point' just because of the 'play' or 'slop' in the rotor mechanism. I've found one low-priced rotor that seems to be adequate (there are undoubtedly others available but I've not surveyed everything in the field) and that's the**Channel Master 9512-A**(or its replacement if a newer model has come along).

ALIGNING THE FEED

The feed or focal point antenna system is crucial to the success of your system. You can lose more signal by having the feed improperly positioned than by virtually any other 'common' error.

First the basics. Your feed antenna is typically a horn which bolts directly flange-to-flange to the LNA. The waveguide section on the LNA is called WR-229 while the flange on the back of your feed horn is a WR-229 'flange'. If you are utilizing a feedhorn with its **own** probe (i.e. ala Howard or Coleman) you will come out of the coaxial fitting attached to the probe through as short a connection as possible to the input to your (homebrew) LNA. Commercial LNAs are universally equipped with the flange **plus** probe; homebrew LNAs usually have a coaxial input connector which must then be connected to the coaxial output connector on your homebrew horn feed.

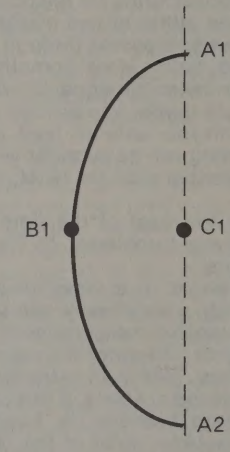
Many home builders have a difficult time deciding what type of coaxial fitting should be installed on the horn probe and the LNA input. The popular SMA fittings are quite easy to work with but they are not strong physically. The type N fittings on the other hand are a tad harder to work with but they have the advantage of being stout (i.e. mechanically sturdy) and you can locate an Amphenol UG 57 B/U which is a male on both ends and use it as a 'splice' to bridge the distance from the probe output to the LNA input. In this way the homebrew LNA can be hung with the LNA supported largely by the mechanical strength of the UG 57 B/U fitting.

Some people wish to separate the LNA from the horn and connect the two with a piece of coaxial cable. This is **not** a good idea since any coaxial cable inserted between the output (probe connection) on the horn and the input to the LNA will have signal loss. This loss is **before** the LNA amplifies the signal and even a few tenths dB loss here is forever lost to system performance. See section in this Manual on Carrier to Noise and Signal to Noise ratios and requirements.

The horn selected should be complimentary to the dish itself. Any dish has a design 'focal length to diameter ratio'; called the f/D. This simply means that the amount of curvature built (or designed) into the dish establishes a relationship between the diameter of the dish (the distance across the front opening or aperture) and the distance out in front of the dish where the dish surface focuses or converges the parabola's intercepted energy from the satellite. The horn has its own geometry. The size of the feedhorn, the 'angle' of the flair, the dimensions across the horn's opening or mouth are all key ingredients to the performance of the horn.

The horn must be designed for a parabola which has a known f/D.In other words, you begin on the horn by knowing (or calculating) the f/d on your dish. How do you determine this if it is not known? Measure and calculate.

WHAT IS THE f/D OF A DISH?



Take a tape measure and measure the width of the antenna'a opening or aperture. That's the (maximun) distance across the 'mouth'.

Set that number aside; it tells you the diameter of the antenna just in case you didn't know it before.

2)**Now measure** from the center of the dish (B1 in drawing here) to the edge or lip of the dish. This is a straight measurement, point to point, not along the surface of dish (which would be greater). This is the radius of the dish. Square (i.e. multiply by itself) that number.

3)**Now stretch** a taunt string across the diameter (measured in step 1). Find the exact **center** of that string, as supported between the two lips of the antenna on either side. **The center will be directly above the dish center.**

4)Take your tape and measure the distance from that center point on the string down to the center of the dish itself (**C1 to B1 on the drawing here**). This is the depth of the dish. Multiply that number by 4.

Now we have two numbers;the radius squared(step 2)and the depth x 4 (step 4).The f/D of your dish is found by dividing the squared radius with the 4X depth number. If you did it correctly and you have a dish that is going to work reasonably well in this service, you should end up with an 'answer' in the .3 to .6 region.

[People in the trade talk about 'shallow' and 'deep' dishes. This can be confusing since what seems like it should be shallow is actually deep, and vice versa. Generally a shallow dish actually has a focal point further from the dish than a deep dish. Generally a shallow dish has an f/D of .5 or greater while a deep dish has a closer-in focal point or length in the under .5 f/D region. Usually a deep dish has fewer antenna 'side lobes'

which means it responds to signals which come to the dish from some side angle better. Better means it rejects or reduces the influence of such unwanted side-angle signals. The most common 'range' of f/D's utilized for this service is.32 to .5 f/D.]

Knowing the f/D of the dish, we then proceed to determine where the focal point will be. How? Well, you have a number (call it .5) and we have the diameter (the first step of the previous equation/test). The focal point will be out in front of the dish surface .5 times the diameter. If it is a 10 foot dish, the focal point will be .5 x 10 or 5 feet in front of the dish.

Now the feed horn again. Remember it must be designed to match the f/D of the dish. That simply means that flair, depth and opening dimensions of the horn have to be massaged together to produce a feed horn which properly 'illuminates' (another word for 'sees') the dish surface of that f/D. Generally the feedhorn is designed to illuminate the very outer edges of the dish so that they are 10 to 15 dB down from the center of the dish. What's that mean?

The feed horn has a pattern or a field of view. It sees the antenna surface **directly in front** of the feed horn **best of all** because like your eye it is less 'sensitive' to things off to the fringes of its field of vision. We can measure or calculate the difference between how well it 'sees' the center of the dish and the edge of the dish and we can calibrate that difference. When we say the feed horn illuminates the edge of the dish - 10 dB (or **down dB**) we are saying that any energy captured by the very edge of the dish from the satellite will be 'seen' or received by the feed horn 10 dB lower in level than the evergy coming back to the feed horn from the very center of the dish.

On the surface it would seem perhaps that we would **like** the feed horn to see all of the dish surface equally well. When it sees the very edge 10 dB down, it is apparent that the energy coming from the edge is making much less contribution to the overall signal level than the energy coming back to the feed horn from the center of the dish. This is true.

BUT - the feedhorn has other design criteria. For example, it has to reject unwanted signals and included in unwanted signals is noise from the earth itself. How's that work?

If you placed the feed horn in position at the focal point and then could magically remove the dish itself while leaving the feed horn in place,what would the feed horn be pointing at? The ground or earth behind where the dish previously was located. At 3.7 to 4.2 GHz the earth is a noise source. It is a transmitter of a sort, you can actually measure the noise coming from the ground. That noise is typically around 300 degrees Kelvin which in dB talk means it is 3.1 dB (or so) 'noise source'. Our TVRO installation, on the other hand, need to have a system noise in the 1.5 dB (or 120 degree Kelvin) region if it is going to perform well. This says that our parabolic reflector, in addition to capturing signal from the satellite, is also a 'shield' that refects or blocks noise from the earth which might otherwise be picked up by our feed horn antenna.

Now then, if our feedhorn were to be designed so that it saw every part of the parabolic surface evenly (probably an impossible design challenge since the real world it becomes apparent that just beyond the edges of the dish the feed horn is stil seeing or illuminating that area.If that area is the ground (it would be) then we would have the feedhorn picking up signal from the satellite via the surface of the antenna and noise from the ground via 'leakage' around the edges of the dish. **The noise would win.**

So we design the feedhorn to have a 'tapered pattern' so that it sees progressively less-well as we get closer and closer to the edge of the dish. It works out that if the feed horn gets to the edge of the dish and ground just beyond the edge is at least 10 dB "down" we will then have reduced the influence of the earth noise on our system to a total degradation of 1/10th of one dB. In other words, the earth is now an insignificant contributor to our system noise.

Now the feed positioning.

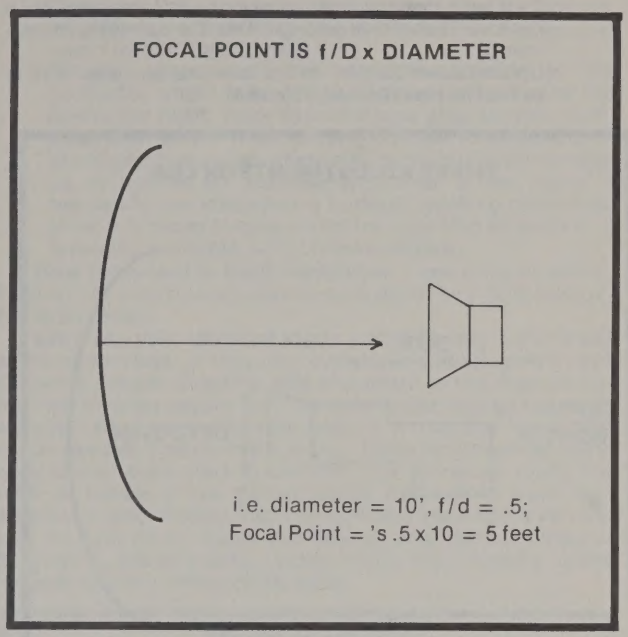
Whether the feed is flanged to the LNA directly or linked via a connector is immaterial to what follow.

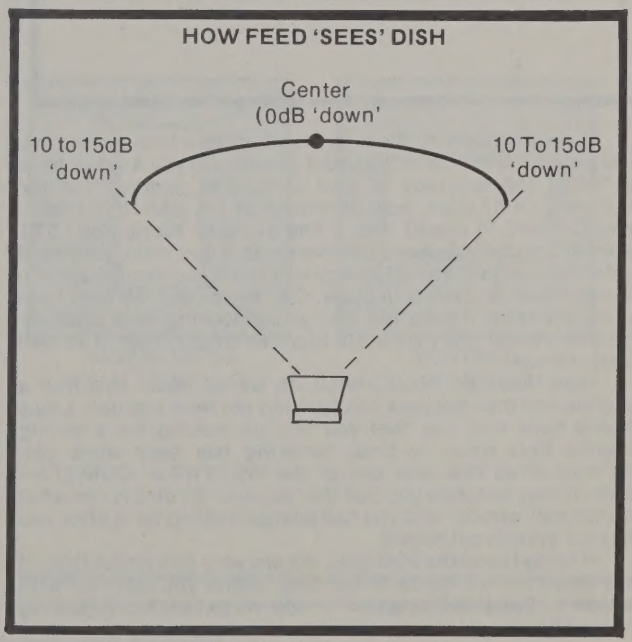
1)**First determine where the focal point should be.** You've already calculated the f/D and from this you know where 'in space' in front of the dish the feed will be located. You are measuring from the exact center of the dish to the center of the opening across the aperture (mouth) of the LNA.

2)**A rigid support is mandatory.** Why? Because movements of 1/8th inch or so will be called for and you can't move it and hold it in position accurately unless you can tie it down.

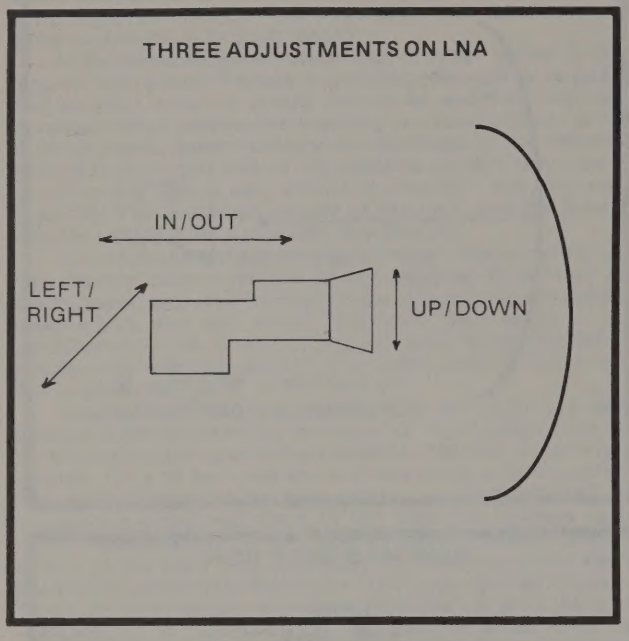
3)**Start with the mouth of the feed horn** spotted where you **calculate** the focal point should be. There are three possible movements for the feed horn.

a)**In and out.** That is, closer to the surface of the dish and further away, but always on a line that comes straight out from the dish center back squarely at the point in the sky where the satellite is located (if you are having trouble determining where in the sky the bird is see 'STT's "**The Satellite Navigator Manual**" by Stephen Gibson).





b) **Left and right** (since we are in the satellite business we'll conform and call this the azimuth adjustment).
c) **Up and down** (again, in the satellite business this is called the elevation adjustment).



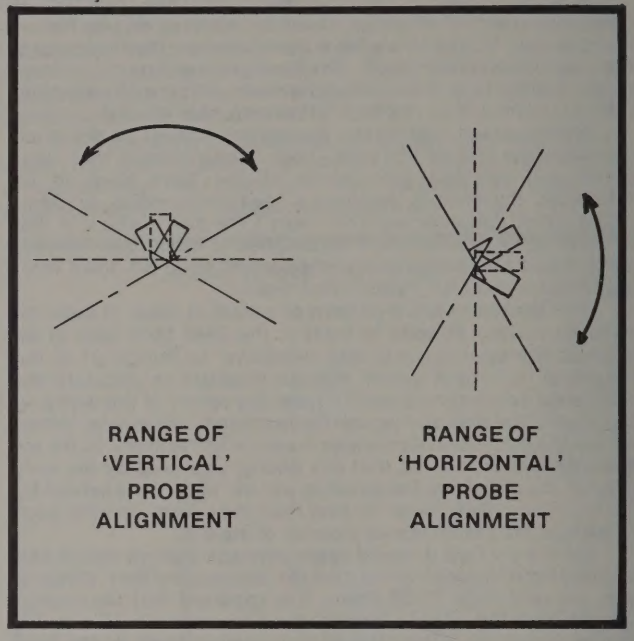
If you are hanging the LNA plus feed horn first, before you find a satellite (which is the usual procedure) you kind of have to 'trust' the accuracy of your calculated position for the feedhorn. Huh? Well, how do you align the dish if you don't have the feed in place? Yes, "**The Satellite Navigator**" STT Manual does tell you how, but even with it you make your **final** adjustment with the satellite signal. Which you cannot do until the feed horn + LNA is in place. OK, so you put the feed horn where you **think** it goes and then you go looking for a satellite. We won't cover this here since Stephen Gibson does it so well in his manual.

Now, having 'trust', what do we do next? We find a satellite and then get back to adjusting the feed position. Logic should have told you that you will go looking for a strong satellite first since no final tweeking has been done yet. For most of us this says one of the WESTAR or COMSTAR birds. It may surprise you but the 'popular' FI bird is not what you can call 'strong' and you had best go looking for it **after** you get your system optimized.

Having found the bird (yes, we **are** very glib about this - it may take your six hours or six days unless you start off with Gibson's "**Satellite Navigator**") now we get back to adjusting the feed horn.

4) First be sure you have the polarization 'square'. **Twist** (i.e. rotate) the LNA + feed horn until you have the strongest signal level; that **aligns your probe** with the incoming wavefront.
5) Now very carefully move the whole package **in and then out** (in is closer to the dish surface, out is back away) and read out the change in signal level. How? With a receiver tuned to an umnodulated carrier as described elsewhere in this Manual. If not that, then with the receiver set on a transponder that has (static) "color bars" up and a CATV type field strength meter plugged into your 70 MHz IF of the receiver (reading the 70 MHz IF signal on the FSM). If none of these suit you, just look at the picture; your eye is a pretty good indicator of signal level and you can come pretty close that way.

[The exception to this is when your signal is into 'full quieting'; that is, the picture is so strong that you can move the feed some distance and not tell a negative difference. In this case find a weaker transponder, or even stick some cardboard over the opening to the feedhorn. You can 'layer' the feedhorm with cardboard to attenuate the signal a bit at a time. Take the signal level 'down' so you have some noise showing and when you have noise then you can see when you are making it better or worse.]



6) Having found the optimun in-out position, stop and take a tape measure and check the distance from the center of feed horn opening (on a line that is flush with the opening of the lip) to the **exact center** of the dish. If you should be 60 inches away from the center and you are 62 inches that tells you something about your dish and/or your feed horn. What? Well, when the actual focal point (where maximun signal is found) is **different than** the calculated focal point, you may have a 'warped' dish. Or you may have mis-calculated the f/D. Or the feed horn may be something other than what you think (its' f/D) is.
7) **Now try left and right.** Be careful to see that you don't hang low or raise high as you swing left and right; remember you are on a 'slant' with the feed horn and-everything is at 'an angle'. Maintain that angle; go just left and right. If the maximun signal is from the center of the dish (you can eyeball it) everything is cool. But if it is off to the side one way or the other, there's a problem.

What type of problem? It could be one of two things. When the dish is slightly (as in less than 2 degrees) off the bird, it **is possible** to get a signal with the system if you also offset your LNA-feed horn by about the same amount. So before you panic, stop and recheck the azimuth **of the dish itself.** Go back through the dish peaking exercise with **the feed** once again **pointed at dead center.** If you discover your error was in the aximuth setting, breath easy.

Suppose you do this and still find the best signal left or right of center. Then what? Well, that says the dish is not truly parabolic; that one side is off from the other. In effect, you are getting gain (i.e. focusing) at the focal point you are located at only from a section of the dish. Probably if you moved your feed in closer or further away from the dish and probed (mover) around the **opposite side** of the dish you would find **another** (second) focus point. If this is the case, stop and get out a taunt string or tape and check the distance from the **calculated focal point** directly in front of the dish to several dozen points on the dish surface. You are looking for some indication that **one side** of the dish is further from the focal point than **the same point on the other side.** Fix it.

8) Now finally the up and down movement. Here again we

hope we find the maximun signal dead-on center of the dish. If we don't, we have the same problem as we theorized we had with the elevation (left-right) adjustment or tweeking of the feed. If maximun signal is dead-on the center, re-adjustment or tweeking of the feed. If maximun signal is dead-on the center, re-adjust everything and lock it down tight. Measure the distance to the feed horn opening from the center of the dish one more time and **write it down** for future reference.

However if the signal peaks low/or high on the dish, this means you may have an **elevation adjustment problem with the dish itself.** A peak **below** center suggests the elevation angle is **high.** Drop the lower lip of the dish (slowly) towards ground. If the peak is **above** center, this suggests the elevation angle is **low**;raise the lower lip higher (i.e. tip the dish backwards). If this corrects the problem you are home free. If not, repeat the same measurements described for the azimuth problem except measure comparable points above and below the center for equivilent distance to the focal point center. If it is off, fix the dish.

Fine points. The typical private installation has a rotator to turn the LNA plus feed horn to align the probe in the horn or LNA with the polarization. When you rotate the feed you must have a small amount of **'slack'** in the LNA powering cable **and** the cable connecting the LNA output to the receiver to allow for this rotation. If you are utilizing a hardline (i.e. 12 to 18 inches long) to run out of the LNA output to the hardline this short piece will have a type N connector on both ends; one end will plug into the mating fitting on the LNA (male on the coax) and the opposite end will plug into a female fitting on the end of the hardline. If you are using flexible cable all the way into the receiver you **still need** a 'loop' to allow rotation of the feed.

Weatherproofing. Flexible coaxial cable likes to soak up moisture. It does not have to actually leak water into it; it will actually collect (i.e. condense) water in the air. I once had a 12 inch piece of cable used as just described soak up so much water than I completely lost signal on a 20 foot antenna!

The solution is **before** it leaks (once a piece of cable gets moisture into it throw it away; don't try to reclaim it). At 4 GHz the moisture required to completely contaminate the cable is on the order of a few drops.

To weatherproof all cable ends (i.e. where there is a break in the cable to put on a connector):

1)**First tape** the connector mid-point (just back of or towards the cable side from the connector end) backwards to the cable jacket **plus** three inches. Pull the tape very tight; stretch it.

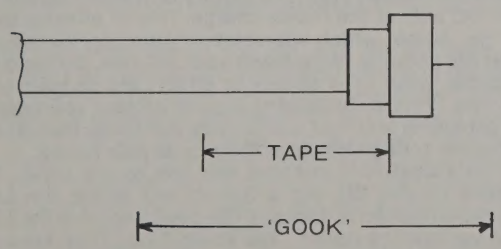
2)**Now install** the connector to whatever it goes on. Make it **slightly more than** finger tight (i.e. use vice grips but don't torque it **too** tightly).

3)**Finally,** 'gook over' the connector starting at the connector where the cable end screws on, back over the connector itself, back over the tape **plus** another inch. Gook with what? There are any number of suitable products which are a jell when they go on but which harden up in normal air temperatures after a few hours. I happen to use inexpensive bathtub caulking compound since it is made to keep water from getting through it, it is readily available, and it is inexpensive.

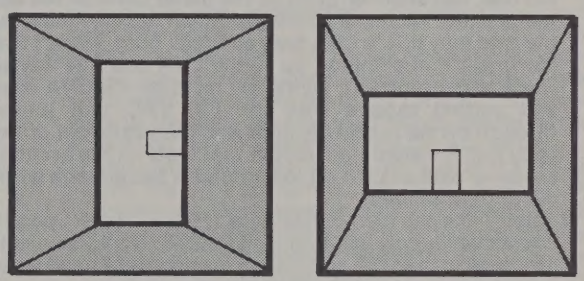
How important is this? Remember - one drop of water, inside either the cable or a connector is death on 4 GHz energy. One lousy drop...

Let's say your terminal starts acting funny; signals are good and then bad, or they may even have quit altogether. We give some trouble shooting aids elsewhere in this manual but the first thing **we** usually do if we suspect the antenna array is take apart **all** of our outdoor connectors. If moisture has gotten in, you **can tell.** The normally shiny finish on connector parts dulls, it may even start to corrode. If a connector looks like water or moisture has gotten inside (remember water can **condense** inside of cable; cable is black and black soaks up heat from the sun) take it apart and clean it. And carefully inspect the cable on the connector; water inside the connector is the first step to water inside of the cable.

WEATHERPROOF CONNECTIONS



PROBE ALIGNMENT



HORIZONTAL
(NULL VERTICAL)

VERTICAL
(NULL HORIZONTAL)

POWERING THE LNA

Getting the proper operating voltages into your LNA should not sound like much of a problem. It turns out that this can be a (very) weak point in the reliability of a TVRO/ARO system.

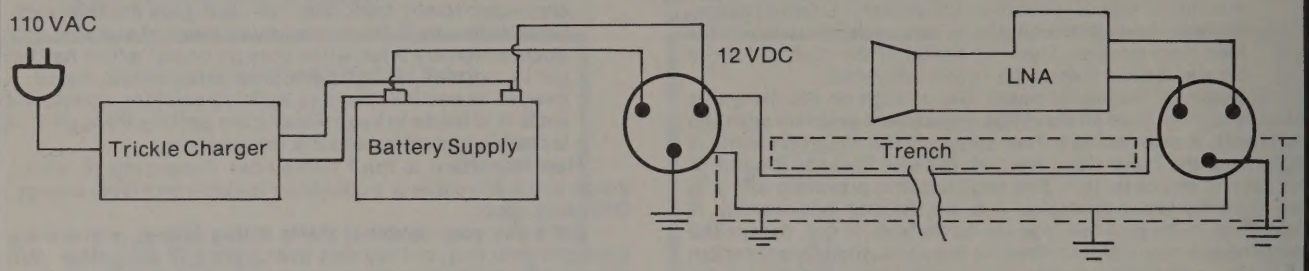
There are two possible voltage types for an LNA; they are not transposible, the one you elect going in is the one you are stuck with. They are 110 VAC or some DC voltage in the 12 to 25 (VDC) range.

With a 110 voltage the LNA converts it in an AC to DC circuit inside to the operating voltages required by the GaAs-FETs and the bi-polar transisitors internal to the LNA. It turns out that most LNA GaAs-FET and be-polar **stages** are designed to function on a voltage between 10 to 12 volts DC.

Thus when you elect to power from 110 VAC you are electing to:

1)Run a 110 VAC line outdoors to the LNA via an overhead cable or a buried cable or (heaven forbid!) an extension cord laid on the ground.

HIGH SAFETY LNA POWERING SYSTEM



2)You are electing to have a 110 VAC to some lower DC voltage power supply built into the LNA.

I have never liked this approach for several reasons. What might they be?

3)Having 110VAC outside, exposed to the weather, with connectors and plugs and what have you is I think dangerous. Ice and snow or heavy rains can penetrate the AC line, can short or jump to the metal parts of the antenna and if you have a fiberglass dish the only metal at the feed may be the LNA case and feed horn. I don't like the thought of climbing up to the LNA one fine day to check something out, laying my hand on the LNA case and getting zapped with the 110 VAC that jumps through my hand into my body and then exits out of my body into the aluminum ladder that rests on the ground. Messing with an LNA off the ground is bad enough without getting zapped.

4)I don't like the idea of having a 110 VAC to DC power converter/supply inside of the LNA box. It creates needless heat in the LNA and heat is the enemy of good looking signals from a cool-running LNA.

Now when you elect to run the LNA on a DC voltage (you make the choice when you order the LNA from the factory or when you build your own), all is not peaches and cream either. Why?

5)DC voltages can also short out. But that's a problem with any voltage around any ground.

6)A DC voltage (like you have in your car battery) is part of the electrolysis equation. Electrolysis? That's when two dis-similar metals have a DC voltage passing between them and the DC voltage causes the two dis-similar metals to form a 'new' compound. Like what? Lift the hood on your car and look at the battery terminals; that white, flakey junk is a 'new compound'.

Since I am obviously prejudiced against running 110 VAC out to the LNA, let's simply say that if you elect to do this you are on your own. And we'll concentrate on the solutions to the DC problems.

The best power supply for an LNA is a battery. Why? Well, because the GaAs-FETs in an LNA have been rightly called 'the world's most expensive fuses'. They are very prone to zapping when a voltage surge/transient/spike comes along the powering line and gets into the LNA innards. YES - every LNA manufacturer takes great care when he builds the LNA to protect the GaAs-FETs. He doesn't want the LNA coming back to the factory with a fried GaAs-FET any more than you do. BUT - it is close to impossible to protect every GaAs-FET LNA against every type of surge/transient/spike that is likely to come down the 110 VAC line. But you thought we were dealing with DC? We are. But a surge/transient/spike that appears on the AC line will also appear on the secondary (i.e. DC side) of an AC to DC supply system. It may not be in its original form, it may not be as stout as it was on the AC side, but it will still be there. Now most AC to DC supply circuits that create a comfortable DC operating voltage (typically in the 12 to 25 VDC range) do have surge/transient/spike suppression circuits or devices. But it is the nature of many transients or spikes (which are best defined as 'very fast rise time surges') that they may occur so rapidly that by the time the suppression devices react to the spike/transient some parts of it (the dangerous parts) have gone by the suppression device/circuits and are on their way to the LNA.

One solution to this is to hang a gigantic capacitor across the line. Another name for a gigantic capacitor is a battery. Here's how it works:

7]Determine your LNA operation voltage range. They have a 'range' of operating voltages (usually 12-25 volts DC or 18-25 volts DC).If yours is 12 to 25 you're in good shape for what follows. If yours is 18 to 25 volts DC you have to work it out on your own.

8)Buy, build, scrouge a small trickle charger; one good for around 200 mA of current at say12 to 14 volts DC. Connect it to the battery. What battery? A small motorcycle or lawn gardening machine battery or a set of Nicads will do just fine as long as they are in the proper voltage range and will handle 200 mA of drain and 200 mA of constant trickle charge.

9)Connect the LNA DC voltage line to the same battery (ies). Most LNAs draw (i.e. consume) between 135 and 200 mA of DC power at their rated operating voltage. If you put in about what you take out the battery will last almost forever and your LNA is powered from a battery that is powered from a trickle charger.

What does this do? Well, the battery is in effect across the line of the DC side of the trickle charge. It is in effect a giant capacitor (or sump) which will catch any surges/transients/spikes that are going to come down your AC line, through the trickle charger (your LNA supply in effect) and to your LNA powering line. This arrangement should protect you against line (AC) problems and that will include lightning that strikes your AC system someplace along the way **to** your house.

Now let's deal with running the line to the LNA. The professionals in this biz dig a trench and shove the LNA powering cable (Romex is fine) and the downline from the LNA to the receiver into the trench and cover it up. They keep the line buried right up to the dish and then 'snake' it up a strut on the dish to the LNA. This is a good idea but it is not lightning or foolproof.

If your TVRO antenna is exposed (i.e. it sits on top of a hill and is the largest metal or metal plus fiberglass structure around) you can reasonably expect it will get zonked by lightning some day. If the dish is metal, it will take the brunt of the blow and the LNA will either survive or be cremated. No telling which. If your dish is fiberglass, it may not attract the

lightning at all although if there is sufficient metal in the antenna struts, support or whatever, the LNA sitting out there by itself insulated from the rest of the metal in the dish may be your best salvation.

If you do bury your cables (we recommend it although in all honesty ours have been above ground for three years) we suggest that at both ends of the trench, where the cables go in and come out, that you drive a six foot ground rod and then strap/wire/connect the shield on the coaxial line and the ground (**third** wire) on the DC line to the LNA to those driven ground rods. Why? To insure that lightning coming in either end does not get to the other end. It will, and can, travel underground through cables!

Most people don't worry about the antenna itself being grounded since you typically dig a few holes in the ground, place some metal re-bar chunks in the hole with some bolts sticking up to mount the dish structure to and the dish connects to those bolts. The whole array is grounded; at least the mount portion is (even with a fiberglass dish). If you **are** in a high lightning area, your dish is exposed (i.e. it stands out against a sky) and you **are worried** about lightning getting you, drive a six foot copper ground rod at each ground-pier point for the antenna and then take some copper braid (which you can scavage by pulling apart some old coaxial cable and flattening out the braid portion) and connect a clean (meaning paint-scraped-away) metal part of the antenna mount to the driven rod. To make sure that connection between the ground rod and the antenna mount stay good (i.e. with a low resistance between them) 'Gook' over the connection with some sealant such as a bathtub sealing compound. If you don't, in time the mechanical connection between the braid and the ground rods will deteriorate and when that happens you'll no longer have a solid ground.

Now you have some questions. Like if the LNA has an operating voltage range of 12 to 25 volts DC, what is this all about? Remember, inside the LNA the actual GaAs-FET and bi-polar stages function on a lower voltage; 10 volts (or 9.7 etc.) is typical. The input voltage (12 up) is regulated **down**, inside of the LNA, to the actual transistor operating voltage(s). If you go **into** the LNA **below** the DC voltage operating window (12 to 25 in our example) the regulator **may not** work (some do, some don't; it is tricky if it does). Which means the LNA also won't work (you won't hurt it any; it just won't work).

Or, what can you do if you suspect a stage internal to the LNA is gone (like in inoperative)? Actually the LNA will tell you (by looking at the TVRO reception) pretty much what has happened. Here are some symptoms:

1) **No signal at all**. Check to see if you have operating voltage to the LNA. If you do, break the LNA supply line and insert a VOM (in a 0-200 mA or so range to read the DC **current** being drawn) in series with the line. If you did this way back when you installed the LNA, you **already have written down** a reference current reading. Has it changed? A change greater than 10 mA indicates something; usually a stage has stopped working if the drain is lower or a stage has shorted if the drain has gone higher.

2) **Signal looks OK** on the low end but the high end is noisey (or vice versa). That says that one of the two first GaAs-FETs is gone. In many commercial LNAs one stage is peaked on the low end (i.e. 3.7 to 4.0 for example) while the other is on the high end (3.9 to 4.2 for example). It is the sum of both stages that produces the gain-flatness in such a circuit. The GaAs-FET may still be operating (as in drawing current) but it could be bad (as in noisey) just the same.

3) **Everything is noisey**. Eliminate the coaxial connections (they may have moisture in them) first. If it is an LNA problem, this indicates a bulk-gain (one of the lower-grade back-end stages in the LNA) has gone.

If you have the ability to provide a varying voltage to the LNA supply line, here is a trick we found quite by accident once when a chip capacitor **plus** regulator quit in an LNA. We started feeding voltage from a voltage variable DC supply to the LNA in the 6 volt range (way low) and nothing happened. Then we slowly increased the voltage to the LNA by turning up on the adjustable pot on the supply. **BINGO.** At 9.6 volts the LNA snapped back to life. As long as we kept the LNA (an SCI unit) powered + /- .05 volts from 9.6 volts it worked just fine. Above or below that 'window' and it quit again. Needless to say that was no permanent 'fix' to the problem but it got us back into service until a replacement could be located.

Now what about the (DC) electrolysis problem? It turns out this is mostly one of those old-wives tales. YES - DC current does do bad things with dis-similar metals. But unless you have an open (exposed to the weather) connection where there are two dis-similar metals, 200 mA of current is not usually enough to form an electrolysis circuit in the 12-25 volt range. It's easy to prevent - keep the DC connections weather proofed!

WHEN IT DOESN'T WORK

To have invested time and money in an exciting project such as satellite TV, and then to have the system not work is frustrating to say the least. Second only to having an operating terminal quit on you at precisely the 'wrong time'!

Let's see what logical steps we should follow when something initially does not work.

1) **All hooked up...and nothing** - This is the toughest one of all because there are so many possibilities. The obvious things first:

a] Inspect all cable from the LNA output through to the input to the receiver. Type 'N' fittings have a center pin which must seat into the female side from the male side. If the pin is not long enough it will fall short. If you installed these fittings yourself and are not familiar with how they go together, have somebody else inspect your work.

b] When you have the LNA cable connected to the receiver, the receiver connected to a monitor and the antenna feedhorn connected to the LNA and positioned towards the dish, the following things should happen even if you are not antenna-pointed at a satellite:

1] Turn on the monitor/TV receiver and let it warm up. With the LNA **off** turn on the TVRO receiver. We assume the TV receiver is dialed to the appropriate VHF channel (typically 3 or 4 or 5) to accept the output of the TVRO receiver. When the TVRO receiver turns on you should see a change in the snow/noise pattern on the TV set. It will typically either darken with a slight increase in the 'roar' of the sound or it may simply get 'clear gray' as the TVRO receiver comes on.

2] Now while watching the TV set screen turn **on** the power to the LNA. There should be an **obvious increase** in the 'snow' level; black and white dots should start dancing all over the screen. If when you turn on the LNA you get (a) No increase in 'snow', or, (b) the picture tube shows bands of white/gray/black across the full screen width, this tells you the LNA is not working properly. Start your trouble-shooting with the LNA.

A lack of increase-in-snow can mean any of the following:

a) The LNA is **dead**

b) There is **no** operating **power** (the DC or AC voltage run to the LNA to operate it)

c) The coaxial **cable** connecting the LNA to the TVRO receiver is bad

d) Or, the TVRO **receiver** itself has problems.

If there was an increase in snow/noise, we at least know the system seems to be functioning, in the electronic sense, although how well is yet to be determined. A system that is working up to this point but which produces no pictures will usually have an antenna or antenna orientation problem. A complete course in 'satellite navigation' is found in the Stephen Gibson STT "**The Satellite Navigator**" manual. Here are some of the pitfalls of setting up an antenna initially:

a) Every antenna has a precise and well defined 'focal point' (see section in this manual dealing with antenna polarization). If the antenna supplier does not specify the focal point and you have no pre-cut struts with which

to mount the LNA and feedhorn at that focal point, you'll have to calculate the focal point and assemble/mount your own LNA on struts. A formula for calculating the distance from the center of the parabolic surface to the front edge of the feedhorn is included in the antenna polarization section of this manual.

If you are off by + /- 0.5 inch you'll see the satellite. If you are off **more than this** or you have a small dish (10 foot or less) the tolerance for being at the focal point gets less and less. Check and recheck the focal point.

b] Alignment of the TVRO dish to the satellite is probably the most common problem of all in a new installation. It may take hours or even days until you find your first satellite (although it need not take more than a few minutes if you have researched the problem and have done preliminary measurements per STT's **'Satellite Navigator Manual'**). Suffice to say that you will never see a satellite that your TVRO antenna is not pointing at. Depending upon dish size, you have to be **within + /- 0.5 to 1.0 degrees** of the correct azimuth and elevation before you will see the first signs of the signal.

If you have looked and looked and still find nothing, and have done your preliminary navigation study and continue to come up 'blank' (no pun intended!) what then? Time to re-evaluate the searching sequence:

1] You start off looking for a specific bird. You have three 'knowns' about that bird; it's elevation above your horizon, it's azimuth heading from your location, and the satellite transponders you are looking for. We assume that you have placed the TVRO receiver on the appropriate transponder/channel before you began! Oops. We know one fellow that spent several days sweeping the sky only to discover he had left his receiver dial on a transponder that was not active on the bird he was looking for!

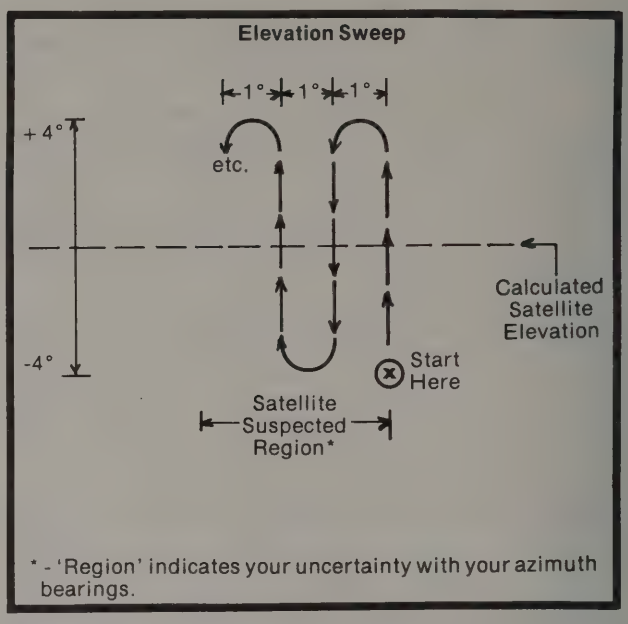
There are two types of 'sweeps' you can do. A sweep is the motion you go through with your antenna as you search to find the satellite.

2] **Elevation sweep** - usually employed with Az-El type mounts. You place the antenna at an elevation several degrees lower than your data says the satellite will be from your location. You adjust the azimuth so that the left-right heading is just left (or right) of where you believe the bird to be. Now with the receiver running (on the right transponder), with the antenna polarization proper for the signal you are looking for, you slowly adjust the elevation up so that you 'sweep' upwards through the geostationary orbit belt. If you don't find the satellite after your elevation indicator tells you that you are several degrees too high, stop and shift the azimuth no more than 1 degree left or right of the starting place. Then repeat the sequence by going down to a point below the belt's height.

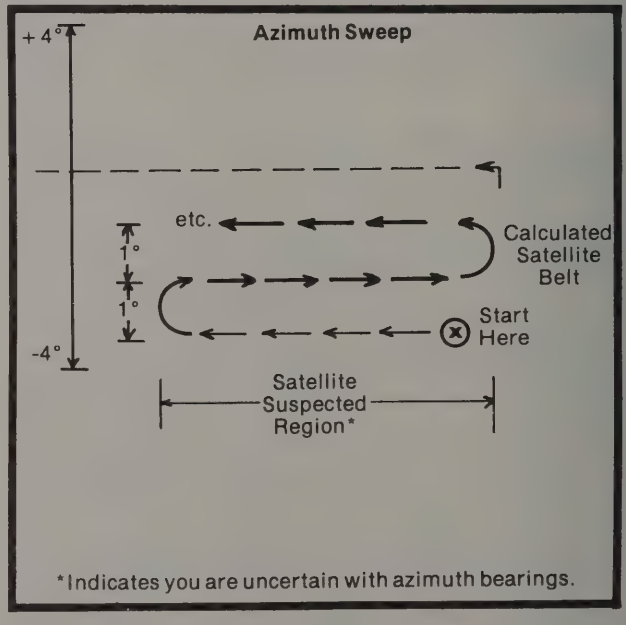
The most important thing about 'sweeping' is that **you do it following a pattern**. Write down the headings you start and stop at each time, check and double check your movements before you start a sweep. The 1 degree 'steps' are maximum because anything greater than this will possibly miss the bird. As antennas get larger the beam width of the antenna becomes smaller or 'tighter' and while 1 degree step may be adequate for antennas in the 10-15 foot size, larger antennas are advised to cut it down to .75 degree steps.

3] **Azimuth sweep** - The alternate to sweeping up and down or vertical elevation is to sweep left and right. This works **best for polar mounts** when the polar mount is **properly aligned** on an accurate north - south line. The procedure is just 90 degrees reversed from an elevation sweep.

a] **First set** your elevation, typically a little above or below where you believe the satellite belt to be. Start left or right by 5 degrees of the intended satellite and work in the opposite direction in a straight line by adjusting the azimuth. Go five degrees past where you believe the satellite to be. Go up (or down depending upon where you began) 1 degree (0.75 degree for a larger antenna) and repeat the process back the opposite direction.



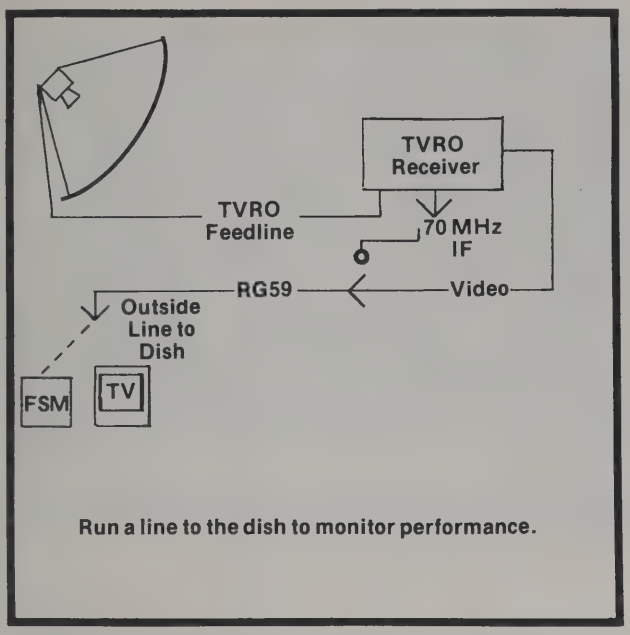
* - 'Region' indicates your uncertainty with your azimuth bearings.



*Indicates you are uncertain with azimuth bearings.

Again, the key to success is to be methodical and to check and double check your elevation and azimuth headings before each sweep. The azimuth sweep will work with a polar mounted antenna primarily because this type of mount **is supposed to** maintain an 'arc-view' of the geostationary/Clarke orbit belt as the antenna moves left and right. However, as Stephen Gibson points out in his **'Satellite Navigation Manual'** a polar mount is no guarantee of complete 'arc-tracking' through the full satellite belt. For this reason it is best to start with a satellite **as close to due south of you as possible** when initially setting up the system (other factors such as choosing the proper satellite also being considered).

If you have reason to believe there may be some terrestrial microwave signals in the 3.7 to 4.2 GHz range in your area, you can use them to check out the operating status of your system. Most TVRO antennas have a difficult time adjusting down to a 'zero look angle' (i.e. directly on the horizon) when they have been installed to track elevated satellites such as most North American users have. This says it may be difficult or impossible to simply 'tip' the antenna forward to sweep the



Run a line to the dish to monitor performance.

horizon itself for terrestrial signals. One alternate is to let something high around you (if there is a building, a tall clump of trees, even a radio tower) act as a 'reflector' for the terrestrial air-borne signals. By pointing your dish antenna **at** the tall object you can expect some of the terrestrial signal to 'scatter' sideways or backwards towards you. By tuning the receiver through the 3.7 to 4.2 GHz band while the antenna is slowly 'swept' back and forth on the taller object you may discover telco telephone and occasionally (network) video links. This will in turn give you an opportunity to 'prove' the system is functioning which gives you peace of mind even if it doesn't produce satellite TV signals!

If you have reason to suspect the LNA or receiver are troublesome, it might be best to look for someone to cross-check with. If there is another terminal in the area, see if you can arrange to take your receiver to it to test. A private terminal operator will usually be glad to let you perform the check by substituting your receiver for his; a commercial installation (local PBS station, cable company) may be less willing but if you explain you simply wish to spend a few minutes hooked up to their antenna to see if your receiver is working, they will usually cooperate. Most commercial installations have multiple (i.e. more than 1) receiver running; they connect two or more to the same antenna/LNA through a power divider device. Such power dividers have 2, 4 or 8 output spigots and by connecting your receiver to anyone of these (such as one not in use at the time) you can check out your receiver and not interfere with their receivers also hooked to the sytem.

The LNA is harder to check, beyond the visual check we mentioned earlier (i.e. turn it on and see if there is more snow/noise with it on than off). A private terminal operator may be willing to let you swap yours out for his but he also may be nervous about your messing around with his carefully positioned feedhorn so be wary!

There is one trick you can employ with the LNA. It works this way.

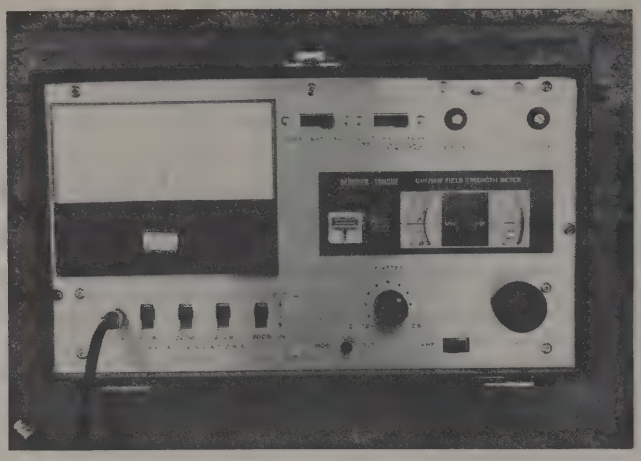
Take a small florescent lamp (12-20 inch) or a regular 60-100 watt incadescent bulb and place it **directly in front of the feedhorn**. The lamp is a generator of **noise** and while you are watching the system receiver when you turn on the lamp you should notice a slight (but perceptible) increase in 'snow/noise' on the TV screen. Move the lamp around within a 1/2 inch or so of the feedhorn (i.e. the feedhorn 'looks at' the lamp). Can you see a change in the 'snow/noise' on the TV screen? **Any increase** in noise **at all** tells you the LNA is working, the feedline is hooked properly to the receiver, and the electronic package is functioning. It doesn't tell you how well they are working, only that they are.

If your receive installation employs an RF 're-modulator' which is separate from the TVRO receiver, a problem between the two can show up as no picture. Remember that what the TVRO receiver produces is 'baseband' video and audio; and before you can view the result on a standard TV set you have to re-modulate the two parts of the signal to a TV channel your TV receiver can tune in. Do you know, for certain-sure, the modulator is working? There are several ways to tell. Take a video tape player and connect the **video and audio outputs** of the player (not the RF output) to the appropriate inputs to the modulator. With the modulator connected to the TV receiver, the tape playback on the VCR should appear on the TV set. Or you can connect the output of an FM tuner or some other **very low level** (not a stereo amplifier!!!) to the video input to the modulator and then play some music or voice through the FM tuner/sound system. The audio frequency ranges won't make a picture but they will cause flashing black and white bars through the modulator on the TV set screen.That will tell you the video section **is** working (but again, not how well). Connect the FM tuner **low level** output to the re-modulator audio input terminals. You should hear sound on the TV set.

To cross check the TVRO receiver video/baseband output locate a baseband video monitor (the type used for monitoring a TV camera output) and connect it to the TVRO receiver. Repeat the noise tests described earlier to see if the switching on of the LNA or a light (noise) source held before the horn produces a rise in noise on the video (baseband) monitor screen.

The most important thing to remember is that other than initial hook-up (wiring) errors, the most common cause of no signal is antenna mis-alignment. It is almost imperative that you have a TV receiver or monitor at the antenna for the initial set up. This may mean installing a temporary (short) piece of cable from the LNA to the TVRO receiver on a table or the ground near the antenna or you can do as I do; run a 'monitoring line' back out to the dish from the receiver location inside. Having a run of low-cost coaxial cable (RG-59/U is fine) extending from the receiver location back out to the antenna is very handy:

OUTSIDE / ANTENNA mounted box contains jacks connected through RG-59/U cables to receiver inside; RF, video, 70 MHz 'IF' and audio.



TUNING a CATV/MATV field strength meter to the 70 MHz range 'IF' from your TVRO receiver provides handy way to monitor satellite signal strength inside or outside at dish.

DIGITAL FSM like this Sadelco unit provides highest accuracy for 0.1 dB signal level changes in TVRO signal; see note about FM 'copy' with AM detectors found in FSMs.

1]You can connect it on the inside end to your modulator and run TV out to the dish for antenna alignment (although this only works if you have a transponder found or a receiver that is switch-tuned rather than continuous; a continuously tuned receiver has to be worked 'back and forth' during initial satellite acquisition efforts to find the satellite).

2]You can run baseband video outside to a monitor for the same purpose.

3)If your receiver has a 70 MHz IF output jack, you can plug this cable into that jack and then connect a MATV/CATV type field strength meter to the outdoor end. This will allow you to use the field strength meter to align or peak the dish.

The use of a MATV/CATV field strength meter for the purpose of getting the dish dead-on the money is often overlooked by the TVRO installer. Here's how it works, and where it can go wrong:

4]The TVRO signal at 70 MHz is **FM** (frequency modulated). It is quite broad (i.e. it may extend from 55 MHz in the IF to 85 MHz with a center someplace near 70 MHz) but as you tune a field strength meter through the ranges you will find that the meter does 'peak' (highest reading) in a couple of spots between 64 and 76 MHz or so.

5]A field strength meter is designed to respond with a **peak meter indication** on a signal that is **amplitude modulated**. The FM signal of the satellite is of course not AM. An amplitude signal is 'peak-level-detected' in the field strength meter while an FM signal peaks in a different manner. If your TVRO receiver is tuned to normal **programming** material, the 'peak indicated signal' at any given instant is totally dependent upon the content of the picture. A saturated color (i.e. such as bright red) will result in a higher 'peak' reading than black for example. Program material **changes content constantly** so as you look at a meter reading the IF signal level on a 'spot' frequency (i.e. the one tuned in by the meter) the indicated level also changes constantly.

6]The solution to this, as best there is one, is to tune in **a static picture**, such as the familiar **color bar test pattern** you will find on the premium service channels before they begin regular programming. Even this 'static display' will not be totally constant in level but the variations will be on the order of .2 to .5 dB indicated signal level rather than 5-7 dB variation in program material.

Any field strength meter used in this application has to be 'eyeball averaged'. If it is a **digital** readout meter (such as those from **Sadelco**) you can simply mentally 'file away' the flitting numbers as they read off in front of you. They flip back and forth over a .2 to .5 dB range and as the 'peak numbers' (highest seen) go up and down you have a way to mentally adjust the indicated readings to the movement of the antenna.

An analog meter (one with a pointer) is a little more difficult to read since they usually have marks in .5 or even 1 dB steps and you are interpolating **between marks** while you are trying to see where it's highest 'flick' registers. It can be done, and using a field strength meter connected to the IF is the best way to really zero in the antenna. But it takes practice.

The next best indicator is the TV receiver itself. However there is this warning; if you have tweeked to the point where the picture is **perfect**, you can't really tell **beyond that point** whether you are improving or degrading the signal. Not until you drop 'off of perfect'. So the best approach is to **pick a weak transponder**, one where you can visually see improvements or degradations in the signal.

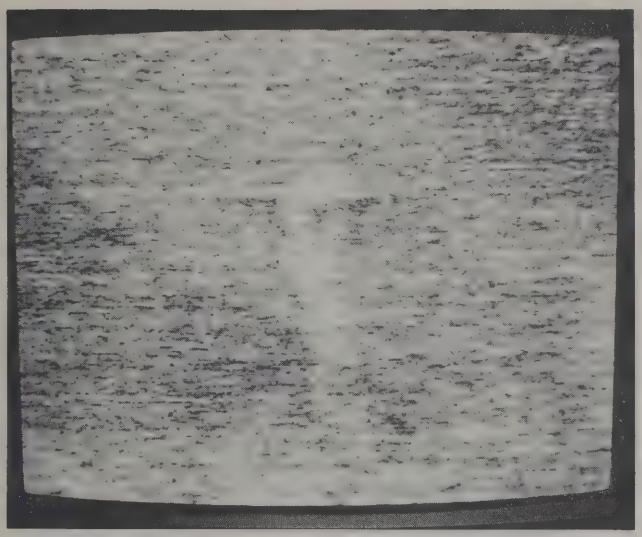
Finally this observation about trouble shooting a system that has been up and running but suddenly quits. The LNA is the first place to look. Take apart the fittings coming out of the coaxial output and inspect them. Do you see any sign of **moisture** in the fittings? Even a small amount (one drop) of moisture can ruin the 4 GHz signal path so be advised. Inspect any coaxial fittings and splices and connections and having satisfied yourself that they are 'dry' then check out the LNA. When it goes, the picture goes and the snow/noise also typically goes. If you still have snow/noise but no picture, this suggests the front end of the LNA is gone. The same is true if the picture is weak (noisey). A weak picture **with reduced snow** suggests one of the later amplifier stages in the LNA has gone; reducing the 'bulk gain' of the LNA.

C + N/N AND SNR

There are many ways to evaluate the performance of a TVRO terminal. For most private terminals the 'proof' of the ''performance'' is in the watching. It either looks good or it does not. That's fine if it looks good, but suppose it doesn't look so hot. How does one determine where the problem(s) may be and then take steps to fix it?

Way back in the dawn of satellite video receive terminals (that would be the fall of 1975 here in North America) there was the belief that all satellite delivered video (plus audio) had to come up to the standards of terrestrial delivered-via-microwave video (plus audio). Those are some pretty stiff standards since through the years the primary supplier of terrestrial video microwave has been the Bell telephone complex and they have never been short on 'reserve margin.'

The Bell terrestrial system has as its 'input' customers the



1 dB carrier to noise produces video signal to noise in 3 dB region.

major TV networks who largely pick up the bill for the transportation of the network TV signals to the major market centers. From the major market centers to lesser markets the TV stations themselves may either pay a Bell tab or install their own supplemental microwave links. In either case what started out as 'Bell' standards end up being TV broadcast standards since the networks virtually insist on certain specifications before they will 'allow' an affiliate to put their programs out through a local broadcast transmitter. By maintaining these standards the networks in turn are able to make certain (positive) representations to their customers, the advertisers. It is a system that works and works well.

When the CATV industry came along and became the first major user of domestic satellite relay in 1975 a new set of standards evolved. They are generally inferior (by measurement number) to the network sponsored terrestrial microwave standards but they are still very good. Like anything in life, sometimes it costs more to get an extra 1 or 2 or 3 % in quality than it does to get the first 99 or 98 or 97% of the content. It was this type of 'trade-off' which CATV went through in coming to grips with establishing its own 'standards'.

Broadcast people want to maintain a signal [plus noise] to noise ratio of 54 dB. CATV opted for a lower standard of 51 dB.

3 dB carrier to noise produces video signal to noise in 14 dB region.

The FCC, in its original approach to CATV earth receive terminals insisted that all such terminals be licensed (this requirement was removed as a mandatory requirement on October 18, 1979) and before a prospective CATV receive terminal could be licensed, it had to show an engineering presentation that indicated to the FCC that the terminal would indeed be capable of a 51 dB signal (plus noise) to noise ratio; SNR.

A 54 dB SNR is a great looking picture; no doubt about it. So is a 51 dB SNR. They say that if you lined up 100 qualified engineers and told them two monitors before them had respectively 51 dB and 54 dB SNR that 51 people would select the 54 as better looking and 49 would select the 51 dB. The one extra guy who elected the 54 dB would be the only one in a group of 100 who could **really** see the difference. Which is another way of stating that 'subjective measurement' by even qualified personnel is simply not reliable once we have a 'perfect picture'. In most of the TVRO world we have a 'perfect picture' at a 48 dB SNR.

Well now, if 48 dB is a 'perfect picture' why did the FCC insist on CATV systems having 51 dB and why do networks insist on 54 dB? There is a logical answer. It has to do with what is done with the video after it is received.

Broadcaster video is routed through the local station equipment and then through the transmitter. There is adequate opportunity here for the 54 dB video to end up in the

11 dB carrier to noise produces [on this receceiver] video to signal to noise in 48 dB region. Yes, that is Ted Turner on left.

51 to 52 dB SNR region before it ever gets 'into the air' on the local VHF/UHF channel. Broadcasters know and anticipate this and start off 'high' so that the final 'telecast' product is still a 'perfect picture'.

The same thing happens in a CATV system. CATV systems function by transmitting their video via RF carriers through miles of coaxial cable and regularly spaced solid state broadbanded amplifier stations. It happens that each time the number of amplifiers 'in cascade' (that's a fancy phrase meaning one after the other like 'in series') doubles (1 to 2, 2 to 4, 4 to 8, 8 to 16 etc.) there is a rather remarkable amount of degradation contributed to the TV picture carried by the cable and amplifiers. In fact, the SNR decreases or drops by 3 dB each time the cascade length of amplifiers doubles. So if we start off with 51 dB SNR at the CATV TVRO site, after the second amplifier we have dropped to 48 dB and after the 4th to 45 dB and after the 8th to 42 dB and so on. Obviously it pays to live close to the TVRO / CATV antenna site!

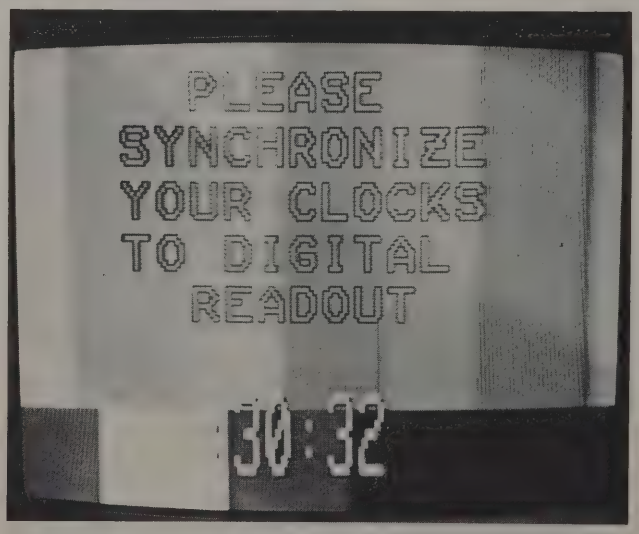
Or does it?

Years and years ago (way back in the late 50's) a group of engineers under IRE (Institute of Radio Engineers before it

51 dB signal to noise may [or may not] be obviously superior to 48 dB [depending upon the skill of our printer!].

became the IEEE) auspices got together and working with Bell Labs and others worked out a system of grading 'public response' to various levels of picture 'quality'. This was the first and last and probably the most carefully constructed 'subjective viewing analysis' ever performed. Hundreds, indeed thousands of viewer impressions were recorded as the engineers carefully changed the quality of the picture on representative monitor screens. The people looked and they voted as the engineers rasied and lowered the SNR. When all was said and done it turned out that any SNR readings over 44 dB resulted in such a fractional improvement in the viewer's eyes that it was not worth while to mess with it. In fact **more than 90%** of those participating in these subjective tests **couldn't tell any improvement** when the picture was **better than 40 dB SNR.**

Hummm. So here we are with broadcasters insisting they start off with 54 dB and CATV starting off with 51 dB. What does that say about the private, low-cost TVRO terminal? Let's look at some simple math and a few basics.



54 dB signal to noise has a crispness to it that you feel you can 'reach out and touch'.

1)**CNR** - generally stands for carrier (plus noise) to noise ratio. Or, the relationship between the amount of 'carrier signal' present and the noise present in the full system. Carrier signal is the 3.7-4.2 GHz signals you are after. Noise is the result of [1] ground noise, [2] terrestrial noise (which may take the form of interference or interfering signals), [3] sky noise, and [4] electronic system noise. You make this measurement before the signal is demodulated and it is most conveniently done at the (70 MHz) IF. It is not a simple measurement however, requiring as a bare minimum a $400-$700 range (used) gadget called a 'power meter'.

CNR is most generally measured by installing the power meter so it reads out the amount of carrier present, and then purposefully **moving the dish antenna off of** the bird, generally **up** a few degrees so as to not intercept other birds to the side, and remaking the measurement only this time you are measuring noise. This is not a foolproof measurement but accuracies within +/- 0.2 dB are possible if the person performing the tests knows what he is doing. Very few private systems bother with this measurement procedure and in truth many CATV do not either.

2)**SNR** - generally stands for signal (plus noise) to noise ratio. Again this is a relationship or 'ratio' between the baseband (demodulated-video) signal and **the noise** that has been demodulated. This test is done **at video**, out of the video spigot of the receiver. It can be done with +/-1 dB accuracy with a well cabilbrated scope if the operator knows exactly what he is doing. More generally it is done with slightly fancier test equipment.

It turns out that under most conditions the eyeball is a pretty decent indicator for SNR. Remember that under the auspices of the IRE back in the late 50's a large group of people participated in a series of tests (called **TASO**) and determined that once the SNR reached 44 dB virtually nobody could tell the picture SNR had improved beyond that point. This test was made using the present NTSC television system **where the video is amplitude** (as in AM) **modulated**. The same numbers do **not** hold for FM and since our satellite transmission system is indeed FM we have to make some adjustments. It turns out that for program material (that means anything other than a test signal / color bar pattern which is static or not moving) when the SNR of an FM signal such as we are dealing with is 48 dB the same 90% of the people who found the picture perfect at a 40 dB ratio on AM would also find the same at 48 dB ratio on FM. In other words, a 48 dB SNR in our FM System is pretty decent. (It turns out that the few percent who still saw improvements in the AM system up to SNR of 44 dB would find the same improvement apparent up to 51 dB in our FM system.)

Now why is there a difference here? Why won't 40 dB of SNR in our satellite FM system be just the same as 40 dB in our terrestrial AM system?

The difference is found in something called the 'FM Improvement Factor'. What in the world is that?

First of all it is the 'best thing going' for satellite TV; without it we'd be all but dead ducks with our small ten to 15 foot dishes. It works this way.

1)**FM** (frequency modulation) is clearly a superior system for transmitting video information **provided** the bandwidth (or the amount of spectrum occupied by the modulating signal) is sufficiently wide. How wide? Well, for the satellite service we have determined that a 30 to 36 MHz bandwidth is ideal; whereas 4.5 MHz is used for normal 'terrestrial' AM (amplitude modulation) systems.

When we talk of bandwidth, we are really describing how we spread the signal out in the 'spectrum'. It works out that AM signals get more noisey when they are spread out widely but inversely FM signals get less noisey when they are spread out in widely (there are limits to this of course).

2)**We reference** the FM system to the AM system and we say that for a bandwidth of 'X' MHz the FM system will outperform the AM system by some known amount. How much? In our satellite video service:

a)**For a 30 MHz wide system** (a system here is the uplink modulation bandwidth and the design of the receiver

[IF] bandwidth) the 'FM improvement factor' is **37.48 dB.**

b)**For a 36 MHz wide system**, the 'FM improvement factor' is **38.72 dB**.

While not totally technical 'pure' we can relate these numbers by simply stating 'FM signal to noise (the video baseband measurement) improves when the FM video signal is spread out over a wider bandwidth; reference an AM signal'.

Humm. So FM gets better than AM by some known, measureable amount **simply because it is FM** when the FM is properly 'spread'. How does that relate to the video signal to noise ratio?

To understand what happens we have to return to the CNR measurement. Recall that CNR is a ratio between the carrier from the satellite and the noise factor of the receive system; the latter a rather complicated number study involving LNA, receiver, feedline, elevation (look) angle and terrestrial interference parameters.

Receiver designers talk of something called 'the receiver threshold'. What they mean, when they say the 'threshold is 11 dB' is that any carrier that is 11 dB or more above (a ratio) the noise factor of the receiver (system) will be noise free. What noise? Noise from the receiver itself.

Most systems are limited in sensitivity by the noise of the receiver; if the LNA is in the 120 to 200 degree K (elvin) range, the antenna is not having to look lower than 10-12 degrees elevation, and the feedline loss from the LNA to the receiver is not too great, the noise 'floor' or sensitivity point (i.e. threshold) for the whole system is largely established by the receiver's contribution to the noise part of the equation.

So we have some amount of carrier from the satellite (a function of the antenna size/gain, the LNA noise plus gain) and we have a 'threshold point' on the receiver. How does the 'FM improvement factor' figure in here?

1]First we take the carrier level (let's call it 12 dB) **from the CNR measurement**;

2]Then we **add** to this number (12) the FM improvement factor that applies to the combination of our uplink FM bandwidth and our receive terminal IF bandwidth.

3]If our carrier level is determined to be **12** (CNR) and we have a 30 MHz wide IF which produces an 'FM improvement factor' of **37.48** dB, our video signal to noise ratio is 12 + 37.48 or **49.48 dB**.

Is it really that simple? Yes it is. The FM improvement factor is added to the known or measured CNR to determine (without even actually measuring) the video SNR! (Of course not everyone will be equipped to measure the CNR so it is not **really** as simple as it sounds.)

As simple as this is, you are possibly wondering then how we get back to the world of high quality video and what happens to the video SNR when the CNR goes down below the previously stated '48 dB SNR threshold-noise-sparklie' point. First keep in mind that we are still dealing with an FM system and an FM system such as we have at work here is noise free **only when** the FM threshold is met or exceeded; and that for virtually all systems this occurs at a video SNR of 48 dB. Any video SNR below 48 dB starts to have 'impulse' noise.

Here is a rule you should fully understand:

"When the FM (satellite TV) **signal is above the receiver's threshold point, the video SNR changes** (goes up or down) **by the same amount of change as the RF CNR. The classic definition of threshold is that it occurs when the SNR deviates from the CNR by more than 1 dB".**

The interpretation of this? Let's say you have a 13 dB CNR and a video SNR of 50 dB. Lower the CNR to 12 dB (smaller antenna, antenna pointing error, etc.) and the video SNR **drops** (also by 1 dB) to 49 dB. Now lower the CNR to 11 dB and the video SNR **drops** to 48 dB. This (48 dB) happens to be the threshold point in our system. **Now drop the CNR to 10 dB and what happens to the SNR?** It is **not** 47 dB (which would be a 1 dB for 1 dB step downward) but rather it is closer to 46.5 dB. Go down another step with the CNR to 9 dB; 2 dB below the threshold point. **And what happens to the SNR?** It drops by more than 1 dB to 44.8 dB. Go down 1 more dB to a CNR of 8 dB. What happens to our SNR? It now drops to 43 dB!

What does that tell us? That we are in great shape as long as we **don't** drop below the receiver threshold; but as soon as we hit threshold the video quality **starts** to deteriorate rapidly.

Now back to the 'FM improvement factor'. Remember it varies as a function of the bandwidth; but for most (30 MHz) wide receiver systems we can fairly say it amounts to 37.5 (37.48 rounded off) dB. What do you suppose happens when the CNR drops so low that the only video left is the 'FM improvement factor' number? If you guessed we just lost our video, **totally**, you are right!

In other words, between the FM threshold of the receiver (call it 11 dB) or 'perfect' pictures, and, the total lack of any video we have a very narrow range of 'satellite carrier levels' within which the picture goes from very good to not there at all.

This is precisely why we 'worry' about such things as .2 dB connector losses and .5 dB antenna pointing errors in this business. If one or more 'degradations' occurs **at the wrong point** in the 'CNR curve' we have an instant and noticeable drop in eyeball picture quality.

A few words about 'threshold'. Some receivers boast a 'threshold extension' system. Commercial receivers in fact now routinely make 'claims' for reduction of their 'threshold point' from the typical 11 dB to numbers like 9 or 8 or even 7 dB. On the surface that sounds like quite an improvement since we now can see that for each dB we can back the real-world threshold down we can back a dB out of our system sensitivity (by making the antenna smaller, the LNA less sensitive and so on). What does threshold extension **really** do?

In the real world 11 dB threshold is both the textbook and the theoretical 'best'. It is inherent with the FM system, and it is not a function really of the design of the receiver (a receiver can be **worse** than this but it cannot - in theory - really be any better.) So how do they make 'threshold extension' claims?

By playing with what happens with the noise (impulse sparklies) in the demodulated picture. One commercial technique has an electronic circuit that sits around waiting for a noise impulse. When it detects one, it attempts to (literally) shut down the receiver video for that fraction of a second when the noise impulse is present. When the noise goes away the picture comes back on. This happens so fast your eye can't see it happening. Unfortunately, when they do this the normally 'white' noise impulse having been removed from the picture leaves behind a 'black' dot. They turn a white fleck into a black fleck!

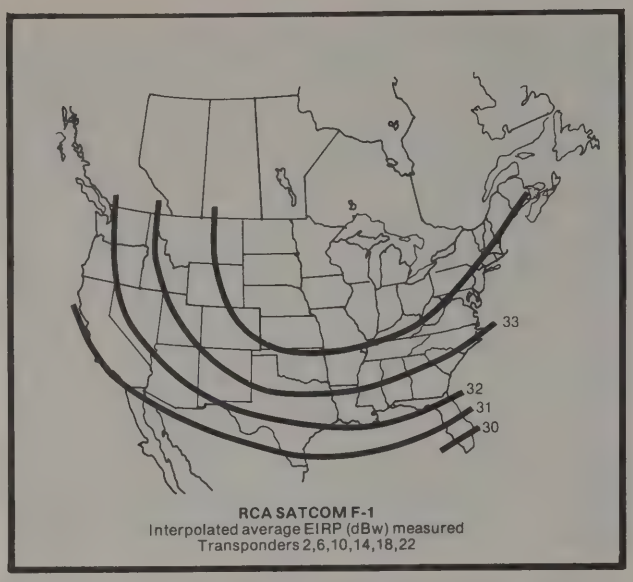
Other threshold extension techniques use tracking filters and they play with the bandwidth of the demodulator stage or even the bandwidth of the IF stage to achieve 'improved' performance. **But this is always done in exchange for some other** (perhaps desirable) **picture element**. For example, if the bandwidth is reduced there is some slight gain in receiver sensitivity but the picture definition (high resolution) degrades.

The bottom line is that even when there is 'threshold extension' the basic fact that it takes a 48 dB SNR to get a sparklie free picture remains unchanged. **You don't eliminate the sparklies when the SNR drops below 48 dB**; with threshold extension you simply **trade** the normal sparklies for some other form of picture degradation.

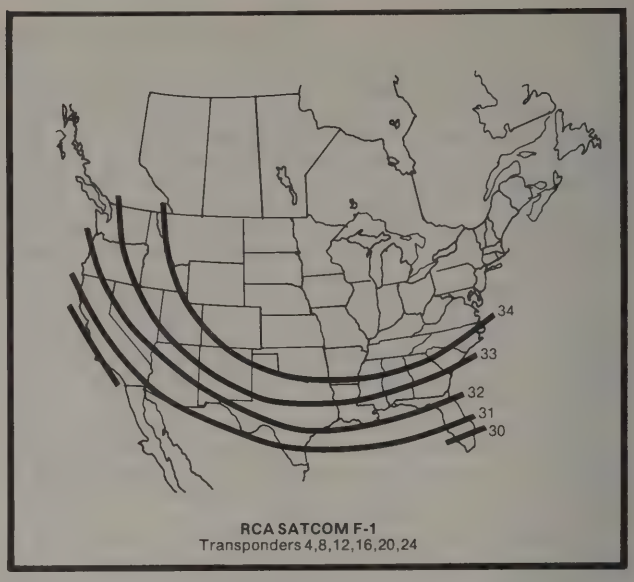
COVERAGE PATTERNS

The Federal Communications Commission requires, before a satellite operator will be authorized to place a bird into orbit, that the operator file with the Commission a set of 'coverage' maps. These maps are intended to indicate the Effective Isotropic Radiated Pattern (EIRP) over the intended service area.

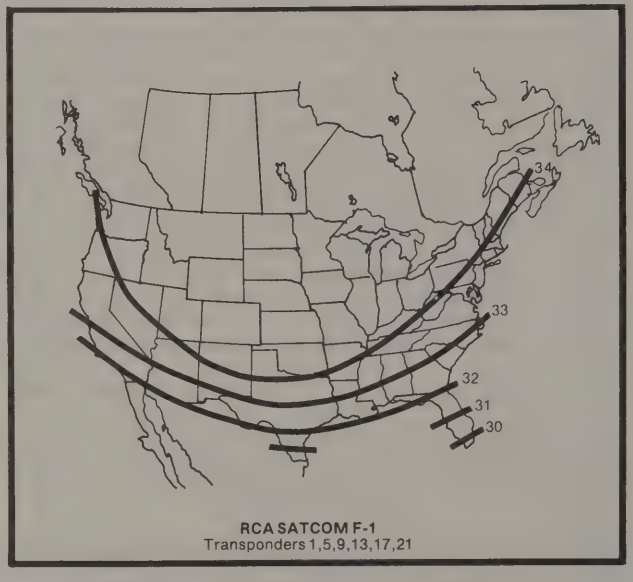
Once the satellite is lifted into its Clarke/geoststionary orbit position it is on its own; it is most unusual for the 'real' antenna pattern or signal coverage contours, to be 'proven' with in-field measurements. Normally the bird's downlink satellite antennas are placed on an antenna 'test range' where the 'pattern' is carefully measured. From these measurements computer programs generate the projected patterns for the earth after the bird is 'on station'. The effort and expense in proving the pattern once the bird is on station is considerable; while a dozen or two spot measurements can be made to verify



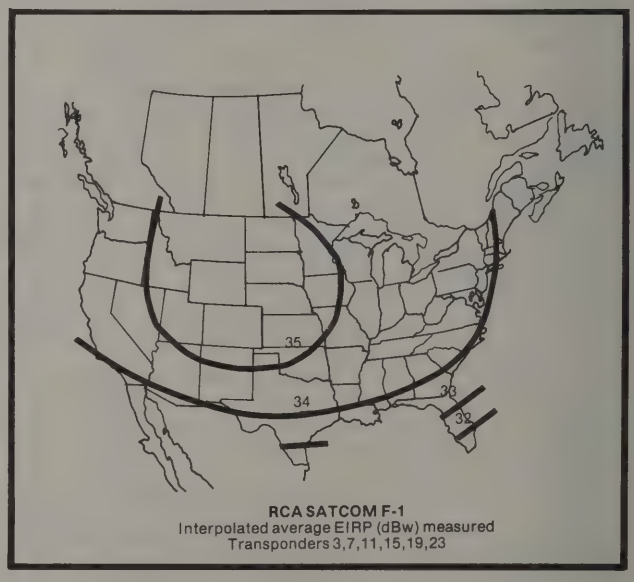
RCA SATCOM F-1
Interpolated average EIRP (dBw) measured
Transponders 2,6,10,14,18,22



RCA SATCOM F-1
Transponders 4,8,12,16,20,24



RCA SATCOM F-1
Transponders 1,5,9,13,17,21



RCA SATCOM F-1
Interpolated average EIRP (dBw) measured
Transponders 3,7,11,15,19,23

(or not-verify as the case may be) the actual operating pattern, to do the job right requires hundreds of carefully controlled measurements with transportable receive terminals that are constantly calibrated against a known reference source.

When the CATV industry switched from RCA's SATCOM FII bird at 119 degrees to the RCA FI bird in June of 1978 there were immediate howls of concern from the CATV industry that noticed right away that FI signal were not as strong as FII signals. RCA had told many system operators this would happen; unfortunately the systems that had anticipated lower signals turned out to be the systems that almost universally had stronger signals, and vice versa. This threw the suppliers to the CATV industry into a tizzy; they felt they were caught in between the RCA real signal contours and customers who expected certain levels of CNR and SNR with the FI bird. Many dozens of systems found that they were forced to upgrade to larger antennas and/or better LNAs after the FI switch.

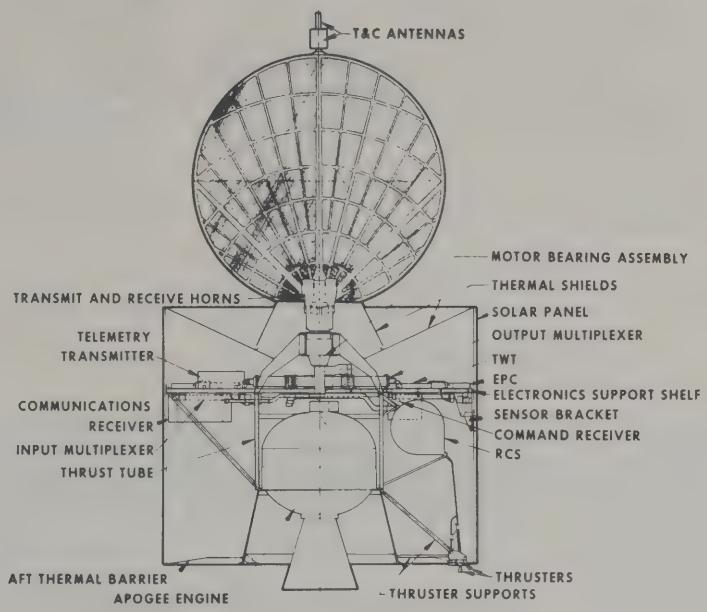
Under pressure the RCA folks decided it might be time to 'commission' an extensive continent-wide field survey of just what the RCA FI signals really were. Under contract COMPUCON of Dallas conducted these field measurements over a period of several months. The results are shown here; four maps, each for separate six-transponder-sets on FI. The significance of these maps is that unlike all other maps printed and generally available (for SATCOM FII, the to-be FIII-r, WESTAR I, II and III, COMSTAR D1, 2 and 3 and ANIK I, III and B) these maps are real.

But are they really real? Let's say they are far closer (+/- 1 dB accuracy is suggested by the measurement people) than the normal pre-launch projected coverage maps for most of the country. Where they may be off is in the southeast; it appears that the levels on some transponders are actually higher in the southern portion of Florida than the maps indicate. This is especially born out by the experience in the Bahamas with 11 foot antennas which in theory should hardly work at all (whereas on some transponders - noteably 1, 5, 9, 13, 17 and 21 - the pictures are totally out of the sparklies or above threshold on an AVCOM receiver and a 100 degree K LNA).

TYPICAL DOMESTIC SATELLITE PARAMETERS

While operational parameter and design considerations vary from family to family of US/Canadian satellites, the WESTAR III satellite currently operational at 91 degrees west is instructive to those readers who wish to understand more about the birds themselves. WESTAR III, like WESTARs I and

II and ANIK I, II and III, and Indonesia's PALAPA I, II, are Hughes HS-333 series satellites so the data here would be almost identical for any of these satellites.



The spacecraft is 5.1 feet (1.56 meter) long, 6 foot (1.83 meter) diameter system weighing just under 600 pounds. the spacecraft structure is a 30 inch cylinder on top of a solid propellant orbital injection motor. Above the 30 inch cylinder is a 5 foot 10 inch electronics cylinder surrounded by the solar array panels. There are 5 horn-fed parabolic antenna systems atop the cylinder; the parabolic reflector is 5 foot.

The solar array consists of 20,448 solar cells each 2 cm square and these cells are capable of producing 262 watts of nominal power. The on board power system contains a pair of nickel cadmium battery systems, each system consists of four seven-cell packs.

Control is maintained by on ground computers plus by two on board (redundant) earth-sun sensor systems. The earth sensors consist of 15 micron infrared wavelength bolometer detectors and telescope mounted video amplifiers aligned 5 degrees north and south of the satellite's equatorial plane; one such sensor points 22.5 degrees east and one 22.5 degrees west of the satellite sun-orbit point. The spacecraft determines antenna azimuth orientation by comparing sun and earth acquisition pulses and an on-board antenna reference pulse. The spin-phase-angle is determined by measuring the sun sensor signal output (after adjustment for propagation delay) and the spacecraft spin axis is derived by comparing sun and earth sensor pulses.

The spacecraft is ranged from two or more locations (such as New Jersey and California or Atlanta and Dallas) and when adjustments in the spacecraft orbital location (i.e. degrees west of the Greenwich line) or attitude (the boresight center) are required a pair of 45 kg hydrazine gas jet thrusters send fuel out through four nozzles as follows: two operate firing parallel to the spacecraft spin axis and two more operate perpendicular to the spin axis line. WESTAR III is maintained with + /- 40 miles (64 km) of its assigned location in space. The spacecraft is mechanically spin-stabilized at 100 RPM and the electronic antennas atop the spacecraft have rotary joints as they do not rotate.

On board electronics consists of 12 separate downlink transmitters each capable of 5 watt output power (when saturated by the uplink signal) over a 36 MHz wide channel. Each channel has a 4 MHz wide guard band between channels resulting in the nominally reported 40 MHz wide channels. Uplink transmissions are directed to the satellite in the 5925 to 6425 MHz band and downlink signals are 3700 to 4200 MHz. The uplink signals are received with three separate horn feed antennas mounted at the focal point of the 5 foot reflector while the downlink transmissions are fed through a pair of feedhorns. The resulting antenna pattern is 3 degrees in height (latitude) by 8 degrees in longitude (east and west) at the 3 dB points. One of the feedhorns utilized on downlink transmissions is offset to provide a spot beam signal to Hawaii.

Downlink telemetering is located at 4198.25 MHz, 4198.75 MHz and 4199.25 MHz; all at 2.5 watts power. Telemetering data from on board sensors includes several spacecraft temperature readings (at different points in the bird), spin rate, spin axis orientation, antenna pointing accuracy, operation monitoring of each active transponder (i.e. power output, etc.), monitoring of the amount of orbital correction system propellant remaining on board, and other key areas of concern.

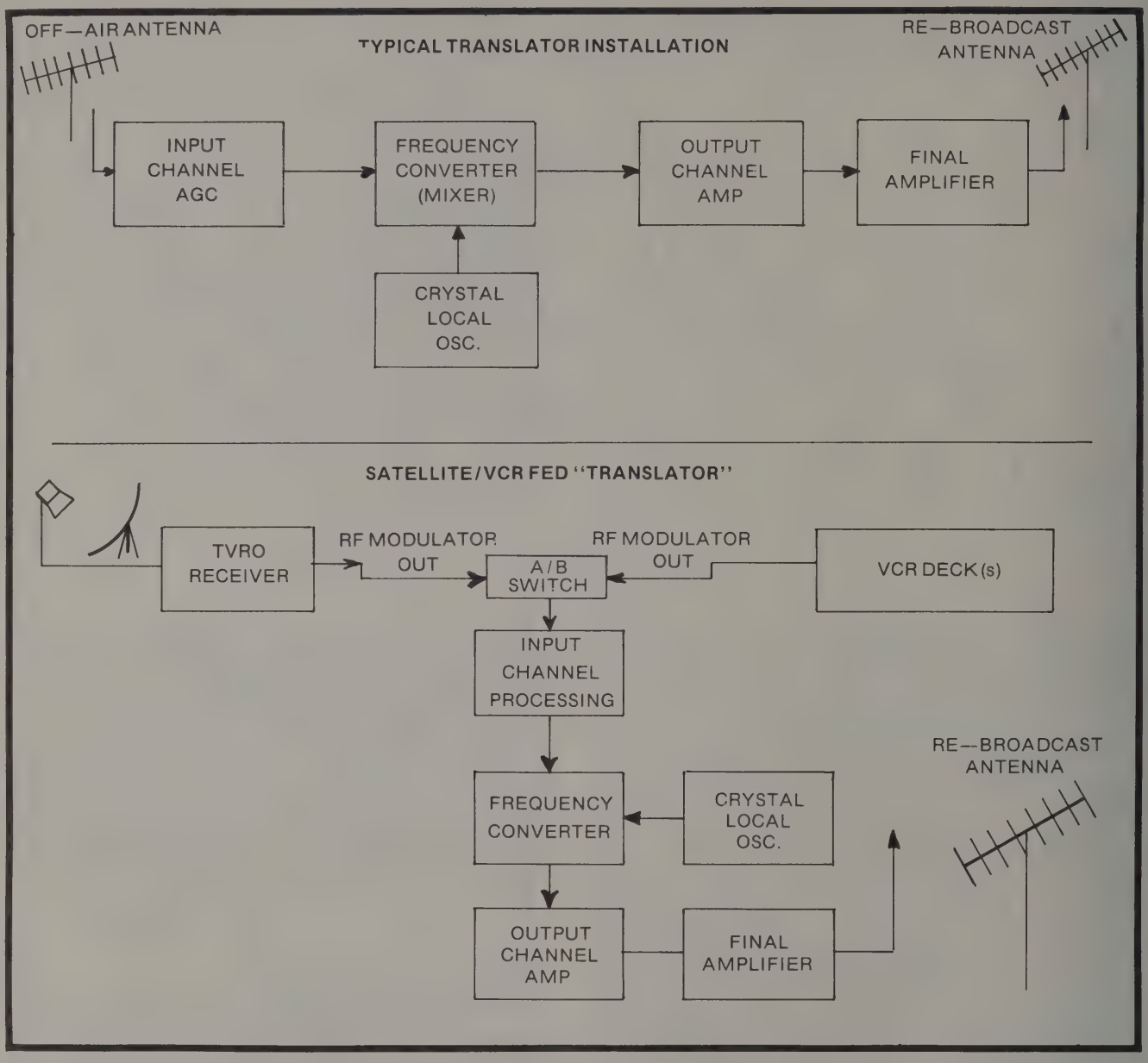
THROUGH AIR RE-DISTRIBUTION

As American and Canadian readers of this Manual are probably aware, our respective government agencies (FCC and DOC) do **NOT** allow a person to be licensed for local through-the-air re-distribution of satellite TV signals, except under some very narrow circumstances. We'll see what those are shortly.

Actually the FCC does allow a device called a translator to be fed by (FM) microwave and that includes satellite (FM microwave). But - the FCC rules governing this service limit such re-broadcasting (throught the air) of satellite signals to the UHF region (channels 14 to 83) and then only when the following meets **their** approval:

1) The signal being received via satellite **must** give the operator of the translator written permission to re-broadcast in his area, and,

2) The FCC is touchy about the **type** of satellite signal that is re-broadcast in this manner. They first said that **only** off-air signals relayed via satellite could be re-broadcast via (UHF) translators. They define an off-air signal as one which actually goes from a broadcasting transmitter (i.e. WOR, WGN, WTBS, KTVU, KTBN on FI) serving the general public to a receiving site where it is picked off-the-air, and then sent to satellite by an uplink and then finally received by a downlink and patched into a (**UHF**) translator.



That's what they **first said** when they modidied their rules in the winter of 1978 to allow satellites to be re-broadcast by (UHF) translators. More recently however the WESTAR service of the Spanish International Network (SIN) has been authorized to be re-broadcast by a 1,000 watt UHF translator in Denver and another in Washington, D.C.. And the SIN feed via satellite is **not** an off air signal; rather it is a **network** signal, less station identification, with lots of dead air time between programs and so on just as you would expect on a 'network feed'. So, it seems that the FCC is somewhat pliable in this area. There is in fact a program under study which would establish translators in the state of Montana to be directly fed by the WESTAR PBS (Public Broadcasting System) satellite service (Montana has no public broadcasting system). This again, if it happens, will be a **non**-broadcast signal feed, directly to a translator, re-broadcast in the local area.

So what is a translator? Well, when they were first 'invented' back in the early 50's they were hilltop or mountain top boxes of electronics and antennas that picked a signal out of the air at the elevated hill or mountain site, amplified the signal on its incoming channel, and then frequency converted the signal to a new output channel where it was again amplified and then fed to a (typically directional) transmitting antenna. People who lived 'down in the valley' below the site directed their own rooftop antennas at the hilltop site, tuned their television receivers to the output channel of the translator and watched the distant TV signals through their ownn local re-broadcasting station.

There are VHF translators (i.e. they output in the channel 2 to 13 range) and there are UHF translators (outputting in the 14-83 range). In the United States the VHF translators are typically limited to 1 watt output east of the Mississippi, up to 10 watts west of the Mississippi (with a few special-case 100 watt units). UHF units can be anyplace from 1 to 1,000 watts although 20 and 100 watt output power levels are common.

VHF units can cover a surprising range with even low power. Like any VHF situation the output power **plus** the height of the transmitting antenna above the (average - surrounding) terrain equals the distance covered. But a 1 watt unit 200 feet above average terrain can deliver a reasonably

good quality signal to people equipped with outdoor antennas cut to the transmitting channel for 10 miles or more. A 10 watt VHF unit will cover a tad further and make the signal stronger within the 10 mile range. UHF units require aroung 20 watts to cover the same region as a 1 watt VHF unit(this is a very rough statement and of course local terrain dictates the actual coverage) while a 100 watt unit will do about as well as a 10 watt VHF unit. A 1,000 watt UHF unit is really a small broadcasting station and 30 mile ranges with 400 foor towers in flatland is not unusual.

Unfortunately the FCC (and the Canadian DOC) take a dim view of connecting up either a VHF **or** a UHF translator **to a satellite TV receiver** unless the basic conditions are met. Again, they include:

1)Having the written authority of the broadcast signal owner / operator to re-broadcast his signals, and,

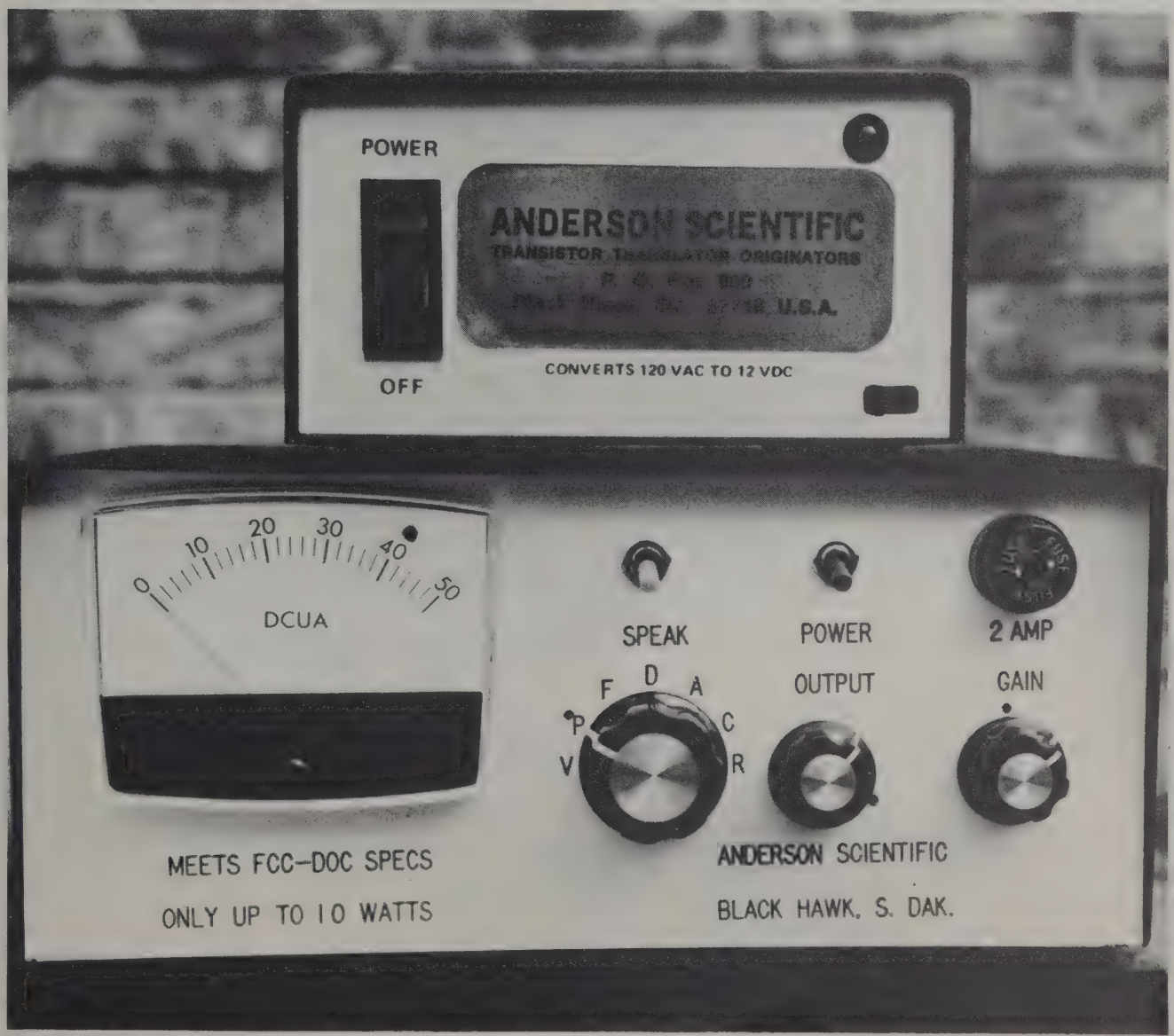
2)Having selected a satellite TV signal which the FCC considers either a 'pure' over-the-air broadcast signal or one close enough (like SIN or PBS) to qualify by interpretation, and,

3)Having a properly approved FCC construction permit / license to do the whole thing.

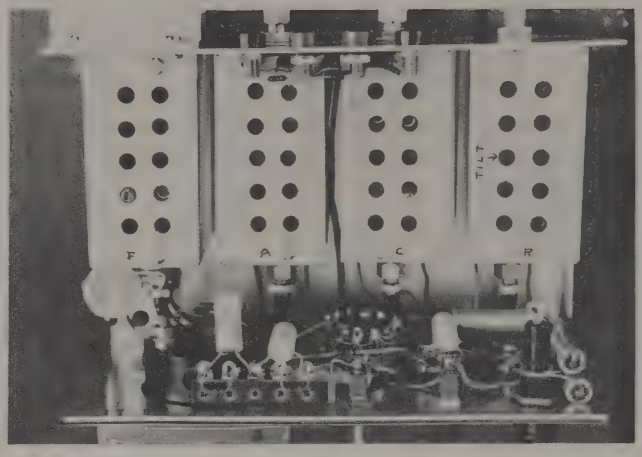
To get a license for this purpose you have to fill out some application forms, attach a copy of your letter of authorization from the station you will be re-broadcasting to certigy you have their permission, and certify the equipment you will be using (i.e. they only approve translator systems which will utilize equipment which has been 'Type Accepted' by the FCC's Laurel, Maryland Lab).

HOWEVER - outside of the USA and Canada there are often no rules regarding such service and many enterprising entrepreneurs have installed translators purchased from US of Canadian sources as a means of re-broadcasting satellite or videotape) programs over a local area.

The small package you see here is a complete 10 watt (peak power) output VHF translator. This particular unit happens to be designed to receive channel 7 and re-broadcast on VHF channel 4. The manufacturer is **Anderson Scientific** (Black Hawk, S.D. 57718; 605-787-4224); and the owner of this firm, Keith Anderson, probably invented the first commercial-



ALMOST LIFE SIZE [90%]ten watt VHF translator with 12 VDC power supply miniaturizes the TV station function.



INSIDE VHF TRANSLATOR - modularized approach handles conversion system and powering.

ly manufactured translator back 1960.

Now how would someone **outside of the United States** use such a unit?

Well, since you can order up virtually any input and any output channel you wish, you simply start by selecting the input channel. If you were feeding fron a satellite receiver with a built-in RF modulator, you would probably want to have the input channel on 3 or 4 to match your TVRO receiver modulator. That way you would go from the TVRO receiver modulator directly into the translator, as diagrammed here. The input to the translator can be any signal in the range from 200 microvolts (-14 dBmV in the CATV/MATV world) up to 5,000 microvolts (+14 dBmV). The 'ideal' input RF level range is 1,000 to 2,000 microvolts and since most TVRO modulators put out around 2,000 microvolts (+6 dBmV) that is a good match.

Once inside of the TVT- 10 Anderson translator the input channel (3 or 4 in our example) is processed; since the translator is normally designed for an off-air signal (one that typically travels some distance to the translator site and which may severe fading on it) the translator has an AGC (automatic gain control) circuit built into it to keep the processed signal 'stable'

After AGC processing the signal is converted in frequency to the output channel. Anderson utilizes a dual-gate field-effect-transistor mixer which is driven by a crystal controlled local oscillator source and the input signal. From here he goes into a low level amplifier stage that produces approximately 1/10th of an (RF) volt output on the output channel (that's 100,000 microvolts).From the low-level power amplifier he goes into an intermediate amplifier that produces between 1 and 2 volts peak signal output. Now we are getting into the 1/4 to 1/2 watt area at 75 ohms.

The final amplifier. These same transistors are commonly utilized as power amplifiers for VHF FM two-way radios in the 20-25 watt region. They are derated to this lower peak power output level for the television service.

Naturally you have to select an output channel someplace along in here; it can be any output channel not harmonically related to the input channel and not adjacent in dial position (4 and 5, 6 and 7 are **not** adjacent). You connect the output of the transmitter to a piece of coaxial line that in turn connects to a 75 ohm yagi or other cut-to-channel antenna and the signal is (re) broadcast over the service area.

Cost. What would something like this cost?

Well, as you might suspect there are many different price levels of this equipment available. The Anderson equipment like anything sold in this field is FCC and DOC approved (it has to be to be used in the States or Canada) and while there is equipment available that can cost far more it is probably not going to work any better. In fact the Anderson equipment is by far the smallest in the field and one of the few packages that is energy efficient to the point that it can be powered by a solar cell array! (That makes it kind of neat because with solar power and a motorcycle battery an installation can be put into a small pole-hung box and forgotten without worry having to run AC power to the 'remote' site; most mountain top sites are remote of course.)

The cost? Here are some Anderson **list** prices (dealers get a discount in the 30% range:

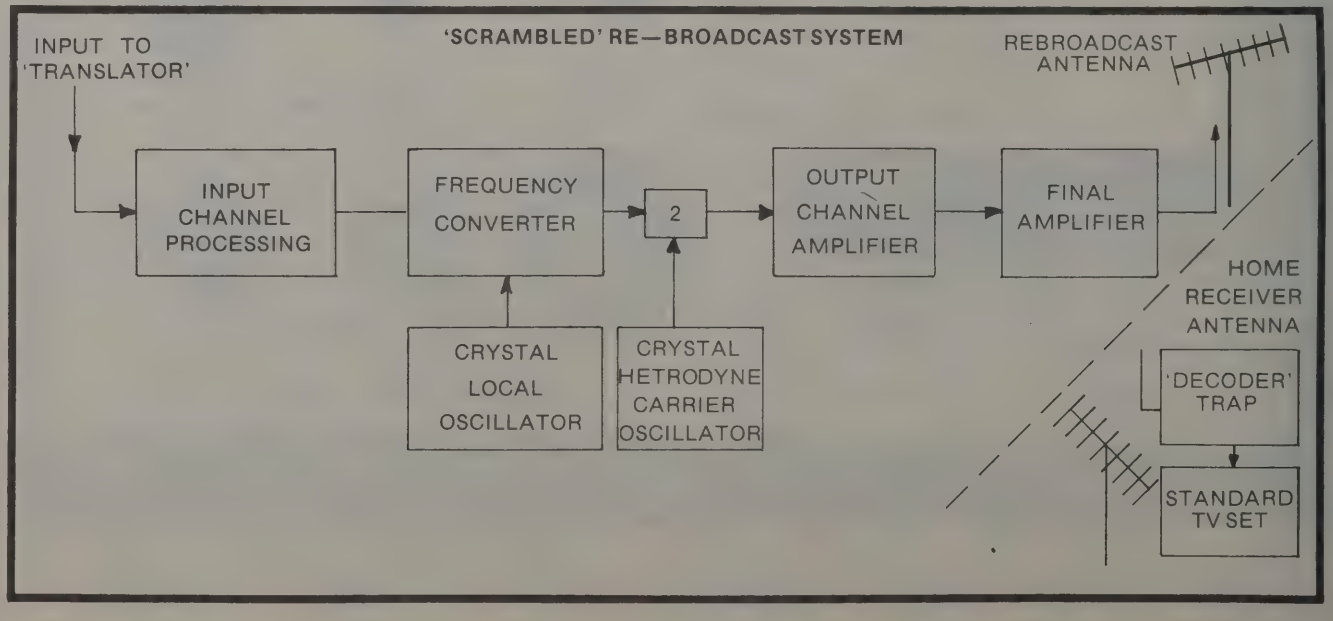
a) **10 watt VHF output unit** - (Model TVT-10 shown here) - $1700 for DC powered unit; add $100 for AC powering.

b) **1 Watt UHF output** - $2000 for DC powered unit, add $100 for AC powering.

c) **5 watt UHF output** - $2600 for DC powered unit, add $100 for AC powering.

The UHf Units are available from channels 14 through 20 by the way; not clear to the top end of the band.

With a dealer discount you could have a 10 watt VHF unit complete with a transmitting yagi (you want to use one of the 'ruggedized MATV or CATV type antennas' to be sure of



having a 'flat' impedance match over the full TV channel), coaxial cable and everything else you need for far less than $1500

Now, how does somebody who wants to approach the re-distribution of satellite signals (in a country where this is not illegal locally) get paid for his service? There are several approaches being practiced. Here we borrow from the CATV industry. It is possible to '**scramble**' the output signal with a 'heterodyning carrier' that is added to the output passband of the transmitter. To **descramble** this signal requires the installation of a "Hi-Q" signal trapping device at each receiver. Here are two sources for the transmitter-scramblers and the receiver-end descramblers:

1)**Eagle Comtronics, Inc., P.O. Bos 93, Phoenix, N.Y. 13135**

Tanner Electronics Systems Technology (TEST), 16130 Skagg St., Van Nuys, Ca. 91409

The transmitter-end 'scrambler typically lists for around $1200 while the receiving 'de-scrambler' (actually a "Hi-Q" notching trap that removes the heterodyning carrier) lists for around $10 each. Systems operating this way in the northern portions of Canada, Central America, the Caribbean and the Pacific typically charge an installation fee in the $25 region and then a monthly fee between $15 and $30 for the service. If you take a pencil, paper and the hand calculator, you can see that it doesn't take long to pay for the elementary equipment (the satellite portion aside)!

SUB-CARRIERS ON THE BIRDS

Most satellite enthusiasts are satellite **'TV'** enthusiasts; since even the most remote regions of the world seem to have some access to audio programming of one sort or another. As another section of this manual details however there are multiple spectrums of audio or other narrow band data available on the satellites; and just as the TV use provides very high quality television service to previously unserved people so too does the audio service uses offer new access to materials either not available locally or in some instances not available at all.

The frequency modulated (FM) sub-carriers differ from the SCPC and FDM-fm services discussed elsewhere in this manual because these are (for audio and data) relatively wideband (75 KHz) services. In fact their use is important to understand since at least one of these FM 'sub-carriers' makes your TV worth watching; it has the sound portion for the TV program!

As a chart here shows the 'baseband' spectrum (labeled sub-carrier spectrum on the chart) is really quite a world onto itself. Here are the uses which it is put to:

1)The **transmission of program-audio** (i.e. audio that goes with the TV signal on the same transponder);

2)The **transmission of alternate program audio** (for example, in a second or third language, also accompanying the TV picture, but not the primary-language audio;

3)The **transmission of** totally **unrelated audio channels;**

4)The **transmission** of **color-sub-carrier** information;

5) The 'transmission **of 'network' instructions;**

6)The **transmission** of **narrow band video** (i.e. 'slow-Scan TV') unrelated to the wideband (full motion) video lower down in the baseband;

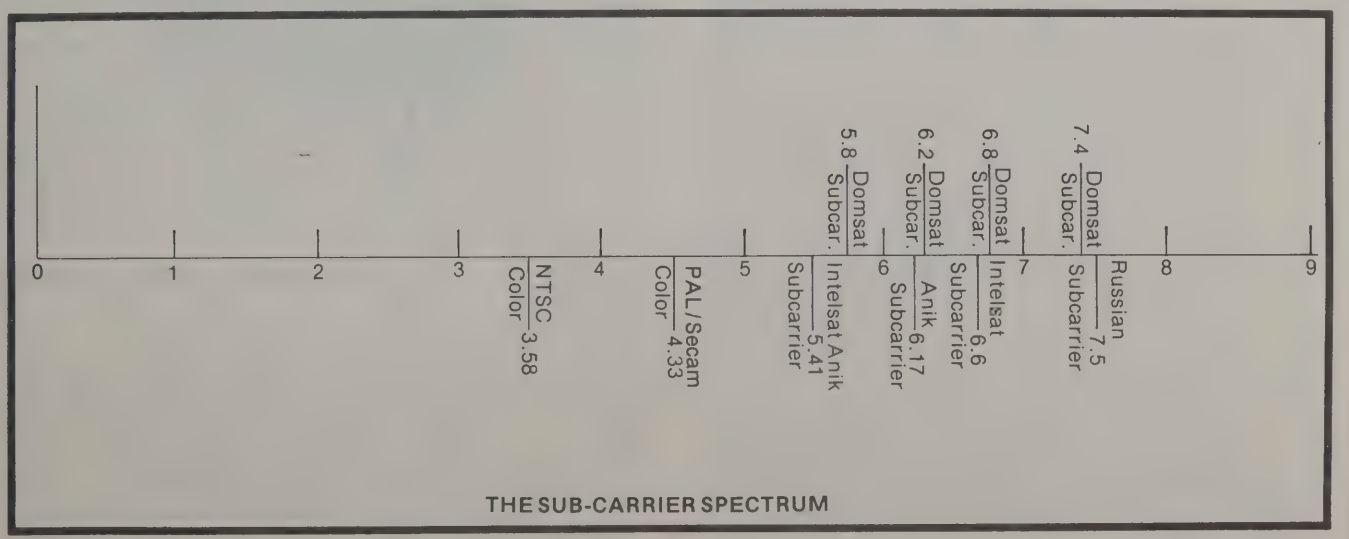
7)The **transmission** of stock market, news and other '**information' services.**

Being able to decipher all of these services would require a host of add-on equipment; slow-scan TV adapter, FAX printers, RTTY demodulators and their printers and so on. However you can and in fact should be equipped for the basic sub-carrier detection since without it you won't have sound for your TV program. Naturally nobody sets out to design or sell a TVRO receiver that is not equipped with at least **one** sub-carrier detector. What you may not realize is that by adding a few additional sub-carrier detectors to your receiver you can greatly increase the operational flexibility of the TVRO system. Let's see how this works and why.

TV engineers require only a portion of the full baseband 'spectrum' to transmit and recover (i.e. receive) high quality color video. In the NTSC (US, Canada, etc.) color system the requirements is that the region from O MHz (or DC) up to approximately 4.2 MHz be kept clear for the basic video information, and the NTSC format 3.58 MHz color-sub-carrier. This is true whether we are dealing with terrestrial or satellite (microwave) video. Anything above 4.2 MHz in the spectrum, however is 'fair game' for adding additional 'channels of information'.

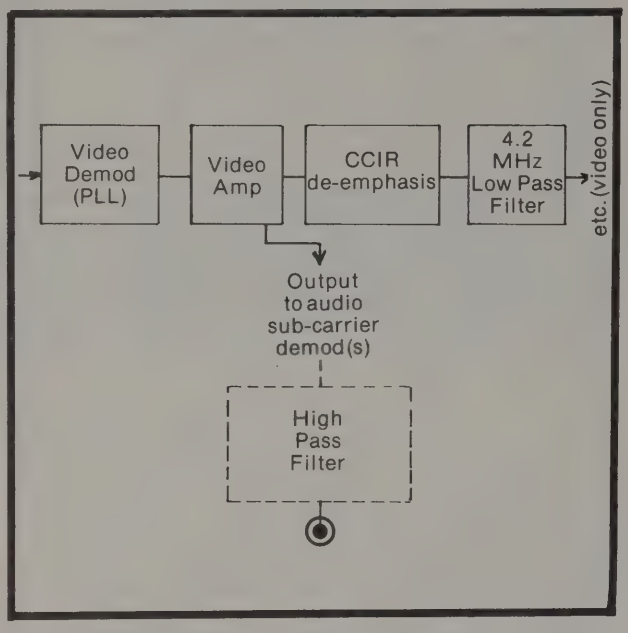
(**Note:** In the Russian Molniya and Ghorizont and the INTELSAT series of satellites the color sub-carrier falls in the 4.33 MHz region. This places the upper limit for video information is these systems closer to 5.0 to 5.2 MHz and restricts use of frequencies below that to video information).

Now could they start stacking in additional 'channels of information' immediately above the end of the video portion? The answer is no but perhaps not for the reason you first suspect. There needs to be a 'buffer' or neutral zone so that in the receivers there is room to separate the sub-carriers from the video information with filters. This is done in US/Canadian DOMSAT receivers by building into the receivers a 'video low pass' filter network; one that allows the **video below** 4.2 MHz to pass , but attenuates or reduces the amplitude (strength) of any information **above** 4.2 MHz. Since such lowpass filters do not filter abruptly (i.e. cut like a knife) there has to be typically .5 to 1 MHz of 'spectrum space' between the last video information (aroung 4.2 MHz in the NTSC system) and the first non-video information. This says that with DOMSAT carriers



THE SUB-CARRIER SPECTRUM

the first 'opportunity' to slide in another (sub) carrier with information is around 5.2 MHz. To play it safe they actually don't start slipping them in until 5.8 MHz with the DOMSAT birds (although the Canadians have experimented with a †.41 MHz sub-carrier).



Let's look more closely at the chart here now.

8) **US domestic satellites** make frequent use of 5.8 MHz, 6.2 MHz, 6.8 and 7.4 MHz. WESTAR places TV (program) audio on 6.2 almost as often as they do on the 'standard' 6.8.SATCOM uses 6.8 MHz almost exclusively although they have been known to use 6.2 and 5.8 MHz for program audio as well, especially when they are concerned about the 'security' of the program audio. COMSTAR being corporately related to INTELSAT likes the 6.61 region (it can be as low as 6.58 and as high as 6.64) but they have been known to use 5.8 and the others on rare occassions.

9) **The Canadian domestic satellites** routinely utilize 6.8 MHz for program audio but have been observed on 6.17 and even 5.41 MHz as well. Their use of the 6.8 MHz sub-carrier is a 'multiplexed' use and on a non-Canadian receiver when you tune in the Canadian audio you hear a strange 'tinkling noise'. You can cure that with the audio sub-carrier demodulator shown here from STT's Wash burn Receiver Manual; a system that filters out the audio data above 5 kHz baseband (which is what causes the 'tinkling' sound).

10) **In addition to** the Pulse Width Modulation (PWM) technique utilized by the Russian Molniya birds they also utilize on Molniya and the geostationary/Clarke orbit Ghorizont birds a 'standard' (to them) 7.5 MHz aural sub-carrier. You can tune it in with the sub-carrier systems related here simply by insuring that the sub-carrier tuning networds will in fact tune as high as 7.5 MHz. Note that on Molniya this sound channel is a radio sound channel or a national Russian radio network; it is **not** the program audio. However on Ghorizont (the geostationary orbit birds) this is the sub-carrier frequency for the sound channel. You may not speak Russian but you will notice on Molniya that the sound does not go with the picture none the less!

11) **On the INTELSAT birds** for years they attempted to keep the sound and video on separate transponders; sending the sound using SCPC or FDM-fm techniques described elsewhere in this manual. However there is a current changeover to sending the audio (program for TV) on a 'standard' (to them) sub-carrier in the 6.61 MHz region. This is especially true with the INTELSAT 'domestic' service feeds for countries such as Brazil.

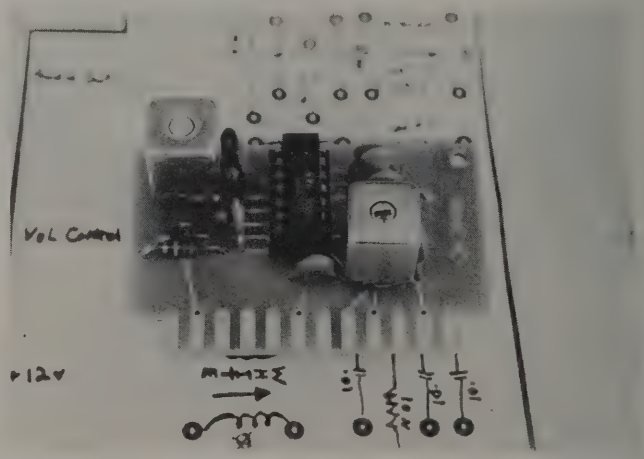
Now what about all of those sub-carriers on SATCOM (FI) which you keep hearing about? If the audio for the TV program channel is on 6.8 MHz, what are they doing with those other audio channels (5.8, 6.2 and 7.4 for example)?

It works out that nobody is attempting to use both 5.8 **and** 6.2 at the same time; they are simply too close to prevent interference between the two. But there are some examples of 5.8, 6.8 and 7.4 being used sumultaneously on one transponder as the table here show.

Hey, what is a sub-carrier? Why it is nothing more than an extra 'signal' (carrier in radio land) that is tacked onto the primary carrier (which transmits the TV video information) in piggy-back fashion. It goes along 'free' hitching a ride.

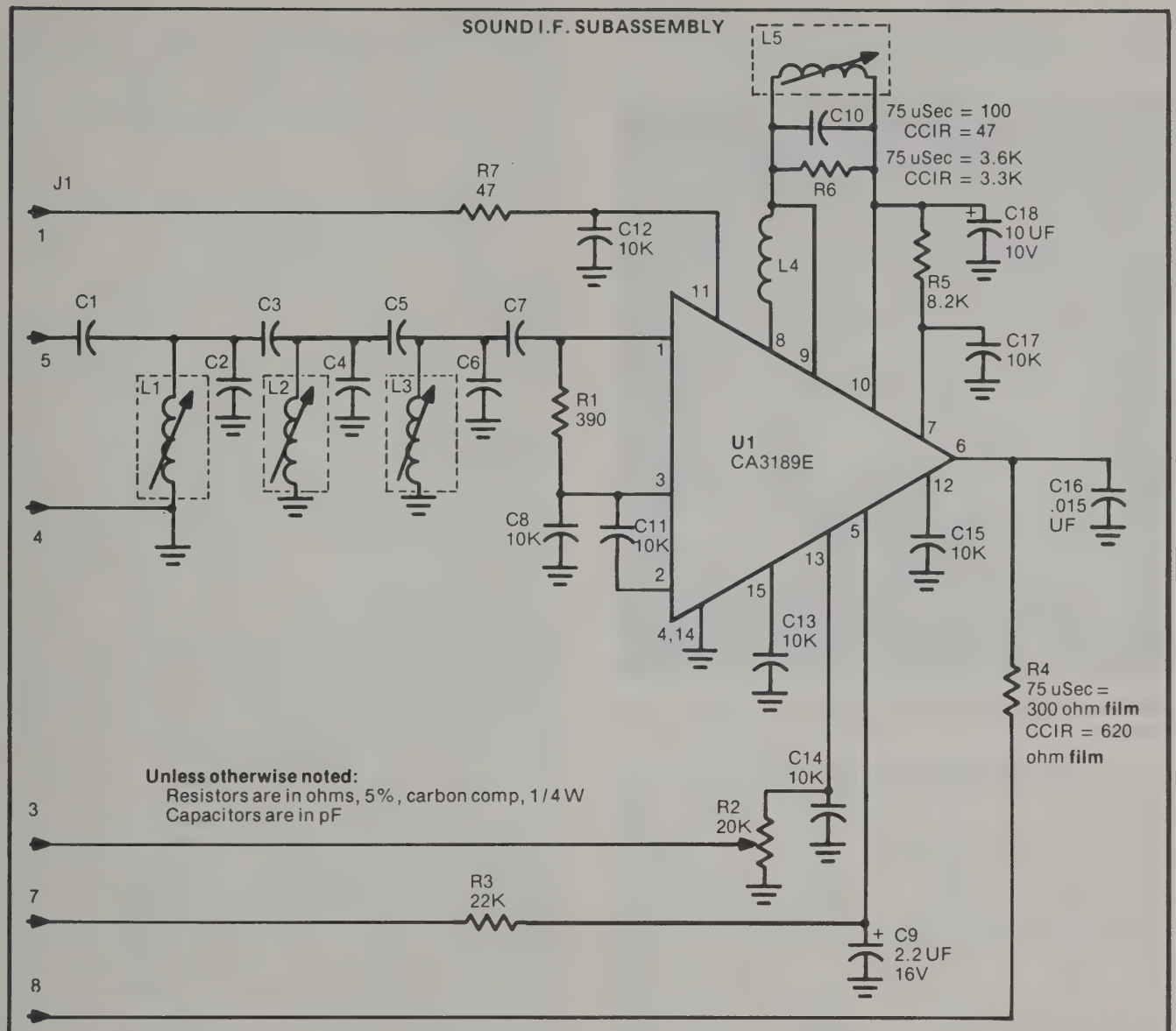
Now how do you receive it? Very simply. You run a wire or cable from your TVRO receiver to a sub-carrier detector. The wire hooks into the TVRO rerceiver ahead of that point where we mentioned they install a video low-pass filter since if it was hooked in afterwards all of the sub-carrier frequencies above 4.2 MHz would be severely attenuated (weakened) by the low pass filter. Typically this 'baseband output' is brought out to the back apron of the TVRO receiver so you can plug in your own add-on detector. Is there a better way to do it? Yes, install a sub-carrier high pass filter into that output line; designed so that it passes only energy above 4.2 MHz. **Is this essential?** No, most sub-carrier detectors will handle the presence of video information down below 4.2 MHz very well (i.e. they will ignore it). But it is the 'pure' way to do it.

The sub-carrier detector. What is this? It is the most simple FM radio receiver you ever saw. The universally utilized LM 3065 'chip' is an FM radio built into a single package. If you connect a frequency modulated signal into it audio will come out of it. A typical sub-carrier detector (the Rohner Machine Works SAA-2 is shown here) mounts on a very small PC board. It has an operation voltage applied to it, an audio output, a volume control and two tuned circuits. The tuned circuits? Well, the LM 3065 is an FM receiver alright but it has to have some help in knowing where it is supposed to receive FM (i.e. on what frequency).So those two coils in the circuit are actually little metal-can tuned circuits with tuning cores. One on the input, one on the output.



ROHNER & ASSOCIATES tuneable audio sub-carrier detector.

Most of the sub-carrier 'rerceiver' suppliers tell you that you need to have a scope and a signal generator to tune up the sub-carrier detectors; to be able to tune the tuning cores in the cans to the right frequency to hear the signal. **That is not the case** if you have aroung 0.5 volt or so of baseband level into the unit. The unit shown here has been installed in a (too large) metal BUD enclosure with a three inch speaker and a two-watt audio amplifier; the kind you see for sale at Radio Shack (etc.)



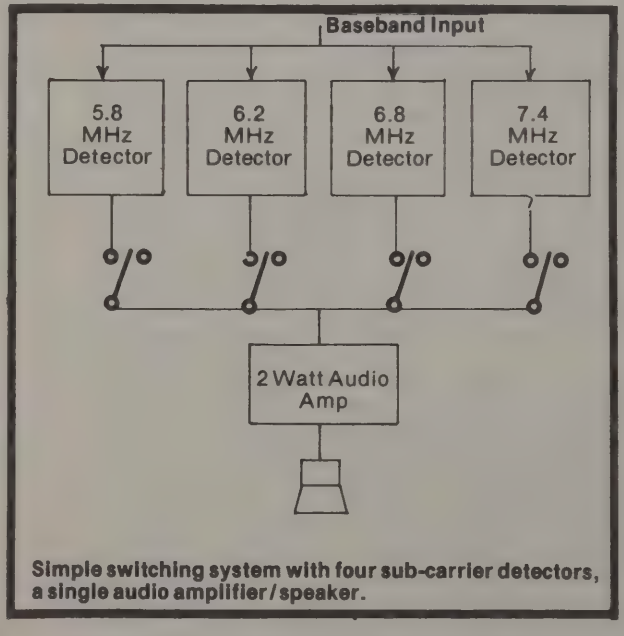
	CENTER FREQ.	C1	C2	C3	C4	C5	C6	C7	L4	L5
75 uSec 75 kHz Δ F U.S.A.	5.6 MHz	150	430	22	560	15	560	43	39 uH	1
	6.2 MHz	110	390	15	470	10	470	33	39 uH	2
	6.8 MHz	110	390	15	470	10	470	33	33 uH	2
	7.4 MHz	82	330	10	390	6.8	390	27	33 uH	3
CCITT 160 kHz Δ F (ANIK)	5.41 MHz	180	430	39	600	22	600	51	47 uH	4
	6.17 MHz	120	360	25	470	15	470	33	39 uH	5
	6.80 MHz	120	360	25	470	15	470	33	33 uH	5

for $7.95 in nice blister-packages. The 2 watt audio amplifier insures that you have enough audio power to be able to hear the music or other information you are tuning in with the sub-carrier detector (receiver).

I have found that all you have to do is tune first the input slug and then the output slug. Generally speaking, when the slugs are tuned (turned) all the way **in** (i.e. or that the slug is down as far as it will go) you are at the lowest frequency region

the unit will tun e (typically around 5.5 MHz or below) and when the slug is tuned all of the way **out** (i.e. just befor turning it anymore will cause it to 'fall out' of the can) you are tuned as high up as you can go (typically 7.5 MHz or higher).

SUB-CARRIER DETECTOR plus audio amplifier and power supply.



Simple switching system with four sub-carrier detectors, a single audio amplifier/speaker.

The slugs on the Rohner SAA-2 track pretty well; 5.8 MHz is someplace close to the 'bottom' of the slug turning range, 6.2 and then 6.8 MHz are a tad higher and 7.4 MHz (or the Russian Molniya/Ghorizont 7.5 MHz) are close to the top. You don't need a scope and signal generator to tune it up; just listen to the sound and twist away!

However - this warning, these slugs are **not made** for **repeated** twisting and turming. They were designed to be tuned some, and then set and forgotten. I don't know how may times you can twist on them before their relatively delicate core material will start to bind and them chip but I would suggest that if you are going to be a sub-carrier tuner-arounder that you invest in **several** sub-carrier detectors; tune them up on the popular sub-carrier frequencies and then leave them alone. Install a simple switching system so that you can switch-select to the appropriate sub-carrier (pre-tuned) detector when you wish.

FI SUB-CARRIER USERS/FREQUENCIES

At the present time here are the major uses/users of sub-carrier techniques on the RCA FI satellite:

Transponder 3 - Chicago station **WFMT** (called the ''nation's best fine-music radio station'' by boosters) is carried 24 hours per day on 5.8 MHz. On 7.4 MHz is 'Seeburg Background Music Service', a 24 hour service.

Transponder 6 - United Press International (**UPI**) utilizes the 6.2 MHz sub-carrier to transmit a special ''slow-scan'' television news service. When you tune this in you hear a 'buzz' sound followed every 12-15 seconds by a tone 'pip'. The pip is a signal telling the buzz (slow scan TV picture) to move ahead to the next picture in the chain. You can't do much with this one without some elaborate slow-scan TV gear and then all you get is still pictures that you'll see in the next day's newspaper. Also on transponder 6, on 7.4 MHz, is a background music service called **'Good Listening Music'**, a 24 hour per day service.

Transponder 21 - On 5.8 Mhz is **'The Disco Satellite Network'**, a 24 hour per day disco music service that does break every 15 minutes or so to identify itself.

NOTE: The audio you will recover with your 'tuneable' sub-carrier detector has two problems. It is electronically treated at the uplink with something called ''pre-emphasis'' and it is designed to work into receivers that are equipped with the equivilent (matched) ''de-emphasis'' circuit. We show such a configuration in the Sound IF Sub-assembly drawing appearing here from STT's Wasburn Receiver Manual. If you neglect to include ''de-emphasis'' circuits in the audio system you will have slightly tinny sounding audio (lacking in lows more than anything else) and not quite the audio signal to noise possible with a de-emphasized circuit. However for anybody other than an andiophile the de-emphasis circuit is not mandatory.

The second 'problem' is that **Section 605** bug-a-boo; ownership rights to the music or other material on the sub-carriers. Remember this is defined by the FCC as **private** stuff so don't record it, don't share it, and most of all don't sell **it!**

LOOK BUT DON'T TOUCH...

You've seen the signs. They warn you to keep your mitts off of somebody else's property. (The sign may also mean the object is delicate or fragile but we'll overlook that meaning here!). About 99% of what is on the satellites these days could, would, and may in fact carry such a sign. In fact, of late some of the visual services have even begun to insert such warnings into their transmissions!

This is no discussion of Section 605 (**1**). Rather, the footnote aside, we are going to ignore for the sake of science and the advancement of technology that there even is such an mis-understood, little practiced FCC 'law' on the books. This is simply going to be a frank and open discussion of what is up there on all of those dozens, indeed hundreds, of 36 MHz wide transponders.

Satellite capacity is huge. We talk glibly about a transponder being 36 MHz wide, little realizing that that takes in everything from sound waves to well up into the lower portion of the VHF spectrum (i.e. 0 MHz to 36 MHz). Do you have any idea how many 10 kHz wide AM (as in broadcast radio) signals could be shoved into that much spectrum if somebody tried? Well, the answer is 3,600. That would be 3,600 even spaced AM broadcast stations, each covering all of North America, each with its own identity, all operating at

once. Or, if you think a 10 kHz 'channel' is very spectrum wasteful, how about 4 kHz single sideband channels? We could stack 9,000 of these in there all at the same time and each (again) would have the ability to 'talk to' anyplace in North America. These are impressive numbers.

And that's for **one** transponder. RCA and COMSTAR have 24 capable each and if **one such satellite** was utilized for AM radio we'd have 86,400 'clear channel' continent wide AM type broadcasting channels or 216,000 4 kHz wide SSB channels to play with. Dare we suggest that even today there are 8 such satellite spots now being occupied by US birds and that if **all** of these birds were turned over to either of our paper models there would be room for (are you ready!):

a)691,200 10 kHz wide AM stations, or,

b)1,728,000 4 kHz wide SSB channels.

Those are such big numbers that we can ignore what would happen with another 8 or 9 orbit spots filled, or with the opening of yet a whole new set of transponders in the 11.7 to 12.2 GHz band. Obviously, there is a lot of stake out there in space. Big bucks ride on what happens and who makes it happen, and, who it happens to.

This section of this manual is about some of the things you can find now, today, inside of these magic 36 MHz wide spectrums. Sure, you know all about TV and the wonderful world of R rated films, unending sports, non-stop religion or Ted Turner's attempt to rewrite the news coverage business with dawn to dawn reporting. But you probably don't know where to tune in the current Kenai Flight Service Weather forecasts from Anchorage, or National Public Radio on SATCOM (and here you thought it was only over on WESTAR; surprise!), or several dozen Holidex (Holiday Inns of America) toll free reservation line circuits or a major computer company's inter-office 24 hour a day satellite relayed executive 'tie-line'...and on and on and on. You also probably don't know where you can tune in the CBS Morning News (which is aired in your town between 7 and 8 AM) perhaps as much as 4 or even 7 hours later in the day. Or learn to speak one of several Eskimo dialects or where to find the manager of the San Juan (Puerto Rico) telephone company talking with his girl friend in San Diego (we bet his wife would like to know that!).

Perhaps you'd settle for being able to dial in the current UP or AP or Reuters wire service (teletype) news, or the latest gold market reports. Perhaps you don't like to read, and you'd like to have somebody read the news to you. Or a popular novel. All of this and much-much more is on satellite.

1)**The Perfect Spectrum** - If our existing radio spectrum between say 0 and 36 MHz was 'perfect', and we used it 'perfectly', it would operate like a single 36 MHz wide transponder on a geostationary/Clarke Orbit satellite operates.

How's that? Well, first of all the 'satellite 36 MHz spectrum' is perfectly divided up (i.e. allocated) so that at precise (4 kHz) intervals there is a new carrier signal capable of carrying or transmitting information from point 'A' (the uplink) to any other point the satellite can 'see'. And since each carrier only carries a single set of 'intelligence' (i.e. voice, data, etc.) there is never a worry about interference. Unlike the 'real' 0-36 MHz spectrum where various groups, nations, users and so on share and then fight over the 'rights' to a particular frequency assignment, in 'private' hands the satellite 36 MHz 'spectrum' is constantly partitioned into descrete assignments and then those assignments are 'protected'; full time.

And unlike the 'real' 0-36 MHz spectrum, this 0-36 MHz spectrum has all signals within it at essentially the same level or strength. That means that as a receiver is tuned across the spectrum each carrier is perfectly separated from those either side of it, there is either no modulation (voice or data, etc.) present because that particular frequency is not in use at that moment, or if there is modulation it sounds exactly as loud as the carriers adjacent to it on both sides and hundreds of carrier assignments removed as well.

2)**The dedicated spectrum** - Unlike the 'real' spectrum where there are constant battles for who uses or controls what particular frequency, the satellite spectrum within a 0-36 MHz transponder is 'assigned' carrier by carrier to those users who have an immediate need for it at that point in time.

That means that when the assigned user has something to say (transmit), he says it; when he is listening to perhaps the return side of his two-way conversation, his side is essentially quiet. When there is no conversation going on, his assigned frequency is also 'quiet'. Each user knows that short of equipment failure, the circuit is his when he wants it, for as long as he needs it.

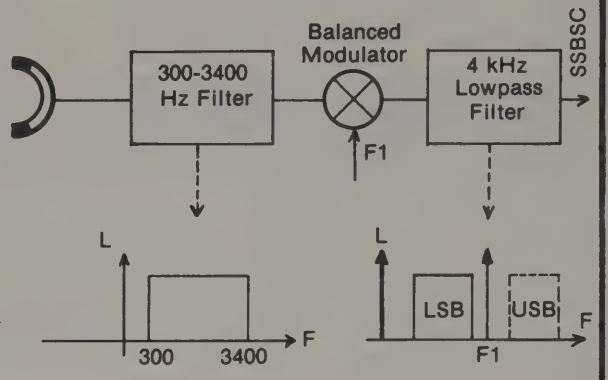
All of this takes a little getting used to; especially if you have had some experience tuning a radio around the real-world shortwave bands or have ever tried to locate a 'listenable AM broadcast station' on the car radio at dusk when you are in the middle of New Mexico.

How It Works

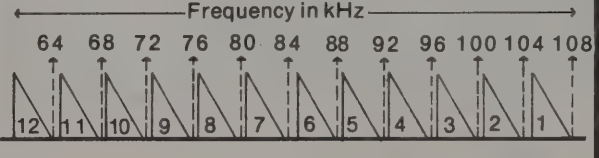
There are two types of voice/data/signal channels on satellite these days. The most common type employ something called single sideband (SSB) as a modulation format. The technical name for this format is frequency division multiplex (abbreviated FDM-fm) which simply means that the baseband modulating frequency range (typically 0 to 7/8 MHz) is treated like a spectrum of its own **before** the uplink transmitter gets ahold of the modulation. Individual carriers are each modulated with voice or data in the 300 to 3400 Hz (that's hertz!) region. The voice / data information is used to modulate a double balanced modulator where one of the two sidebands is eliminated with a filter. The remaining (sideband) signal is **then applied** to another carrier typically operating on some precise frequency between 64 and 108 kHz. These sideband modulator carriers in the 64-108 kHz region are then multiplexed or mixed together in **Groups** of 12 to form a larger group of carriers called **Supergroups**. A Group has 12 carriers, a Supergroup has 60 carriers (consisting of five groups). The Supergroup can be applied as a package directly to the baseband modulator of the uplink transmitter (which frequency modulates - fm's - the uplink transmitter) and they can in theory be placed anyplace from 0.0 MHz up to 10.75 MHz; that's the 'spread' of the baseband modulating frequency (index).

---

[1] Section 605 of the Communications Act of 1934, as amended, generally warns you that non-broadcast-class communication signals are considered 'private' communications. The 1934 act was designed to establish guidelines to prevent unauthorized 'third parties' [i.e. anyone not associated directly with the 'private communications'] from setting out to intercept such private communications. Section 605 warns that any person not authorized to intercept such transmissions and who does so, either on purpose or accidentally, shall not divulge to any other party any of the following: (a)**that such a transmission exists,** (b)**the content of the transmission 'intercepted'. In another section of the FCC rules, the FCC Treats al microwave [i.e. satellite] communications in the 3.7 to 4.2 GHz band as 'common carrier' transmissions, and thereafter confirms by definition that all common carrier transmissions are considered non-broadcast [as in private] transmissions. These rules were adopted at a time when the primary concern was with 'eavesdropping' on private overseas and domestic telephone communications and in studying the debate of the era it would appear that the real concern was with** employees **of the telco/common carrier who might have access in their work routines to these circuits. The Congress clearly was worried primarily about common carrier** employees **eavesdropping. In the intervening 46 years the whole nature of communications has changed including the use of some common carrier transmission frequencies for non-common carrier type signals. The satellite relay of television signals such as Chicago's WGN or radio signals such as Anchorage's KFQD does not fit the meaning or intent of the 1934 act, as far as 'eavesdropping' on a** 'private' **communications channel is concerned. No significant enforcement actions** (by the FCC) **have ever occurred in the 46 year history of Section 605 and the FCC is currently studying this antiquated section of law with an eye towards revising it to modern standards.**



LOWER SIDEBAND AUDIO SIGNAL IS GENERATED IN BALANCED MIXER AFTER 300-3400 Hz PROCESSING



Basic Group of 12 "4 KHz" Voice Grade Channels in 64 to 108 KHz Range; Each Channel Modulates Carrier Separately. (Type B Group)

We'll see how all of this impacts on your receive terminal shortly; don't panic!

Now because this 'spectrum' can, and in fact is, carefully controlled by the uplink terminal operator, he wants to pack as many of these Supergroups into the basic 0.0 MHz (low end of 'band') to 10.75 MHz (high end of 'band') frequency range as possible. To do this, and to insure that equipment installed in Nigeria is compatible with equipment installed in Boise, a set of usually-followed 'baseband allocations' have been adopted. Now these are not totally universal, but they come close. And when you are dealing with 'allocations' within the same bird family, they are identical from transponder to transponder and bird to bird almost all (nothing is 100% in **this** life!) of the time.

A Supergroup of 60 carriers (each with its own modulation or information) is nice but that is hardly large enough to accomodate the needs of the fast growing satellite business. So there is an even larger group called a **Mastergroup**. This consists of five of the Supergroups all mixed together at the baseband point before they are applied to uplink transmitter. Let's see how all of this fits:

a) **Group** - consists of 12 carriers, each 4 kHz from the nearest carrier in the same Group, each capable of being modulated with audio or data with its own 'baseband' frequency range of 300 to 3400 kHz. The basic carriers start off in the 64 (68, 72, etc.) to 108 kHz region where they are 'modulated' with single sideband (lower sideband) techniques.

b) **Supergroup** - consists of five Groups all multiplexed together, plus five 'multiplexing carrier frequencies'. That means we actually have 13, not 12, carriers per-Group in a Supergroup (see diagram here) and a total of 60 useable (for modulation) carriers in a Supergroup plus five more that are part of the multiplexing process.

c) **Mastergroup** - consists of five Supergroups, again all multiplexed together, plus one additional multiplex-mixing carrier per Supergroup. This works out to 60 useable carriers per Supergroup times five or 300 useable carriers per Mastergroup.

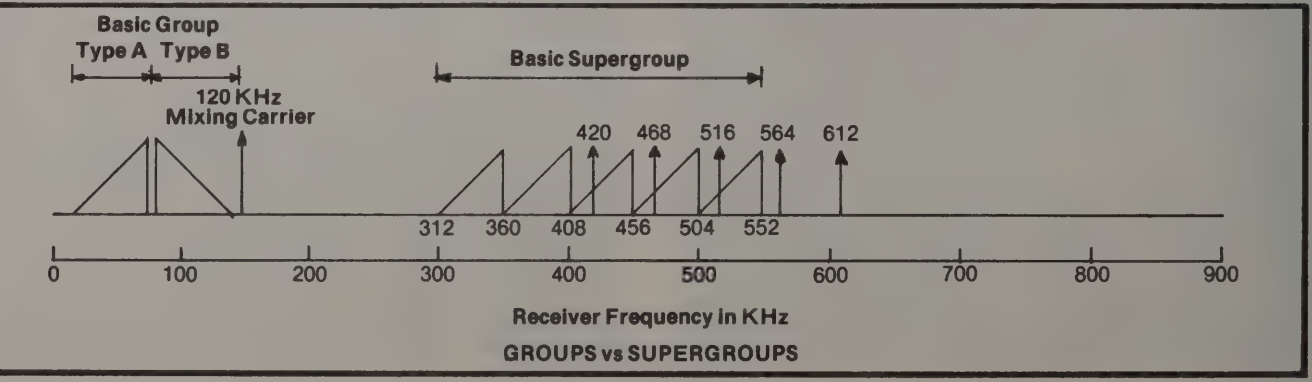
Spectrum. A Group occupies 48 kHz of space; a Supergroup occupies 240 kHz of space while a Mastergroup takes up 1200 kHz of space. Got that? Well, it's not quite true! Actually, a Group does occupy 48 kHz and a Supergroup does occupy 240 kHz (that's 5 times 48) but a Mastergroup occupies **1232 kHz** of space, not 1200. Why? Well, between each Supergroup in a Mastergroup there is an 8 kHz buffer or guard band. We've diagramed it here.

Now, why do they do all of this monkey business? To provide flexibility to the handling of 'batches' of carriers; or Groups/Supergroups as they call these batches. Let's see why this is done.

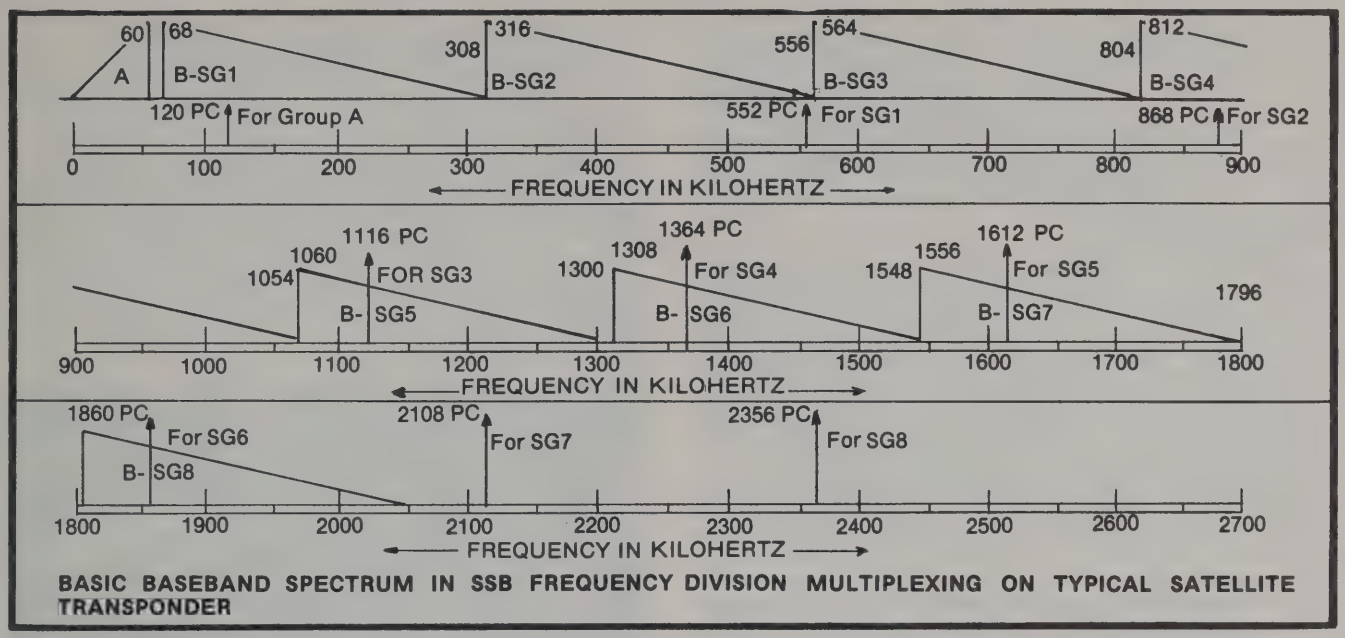
At The Uplink

At any given uplink site there is typically more than one customer who is willing to pay the tariff rate for a dedicated (or non-dedicated meaning less than full time) carrier-channel. IN a metropolitan area such as New York City, there may well be several hundred users of the service and system. So at the New York City Toll Operations Center (TOC) all of the local customers come into the facility on either dedicated telco lines or by radio. Each is processed separately at this point of entry and then the satellite TOC operator 'looks at' each user and see **where** he is going. If there are 12 users who want to be linked between New York City and Los Angeles, for example, the TOC operator selects each of these and 'bundles' them into a Group. Then he may have 52 that want service between New York City an Chicago; These he bundles into a Supergroup (by utilizing 5 Groups). He now has a set of 'bundles' each with the same (metropolitan area) 'point of origin' and each bundle is destined to end up at a separate point of delivery.

The various Groups and Supergroups (and perhaps even Mastergroups) are then all multiplexed (added together) at the TOC and sent on to the uplink site. They arrive there in a


Basic Group
Type A Type B
120 KHz
Mixing Carrier
Basic Supergroup
420 468 516 564 612
312 360 408 456 504 552
0 100 200 300 400 500 600 700 800 900
Receiver Frequency in KHz

GROUPS vs SUPERGROUPS



BASIC BASEBAND SPECTRUM IN SSB FREQUENCY DIVISION MULTIPLEXING ON TYPICAL SATELLITE TRANSPONDER

configuration where they can be applied directly to the FM (frequency modulating) system of the uplink transmitter. For sake of discussion, we'll say that within the uplink modulation baseband of 60 to 108 kHz we have a Group or bundle destined for Los Angeles while in the 312 to 552 kHz region we have a Mastergroup headed for Chicago.

At The Downlink

The downlink receive terminal in Los Angeles will receive **everything** on the transponder; however, it will (by instruction) pick-off **only** that (example) Group of signals between 60 and 108 kHz for local delivery. It will do this by demodulating all of the signals on the transponder to the baseband spectrum of 0.0 to 10.75 MHz, and then using block-conversion techniques extract the 60 to 108 kHz bundle. Since the downlink receive site is typically some distance outside of the metropolitan area itself (Los Angeles is located at a place called South Mountain for RCA) and because the destination customers are likely to be **within** the city itself, this 'bundle' is then transferred to a terrestrial microwave circuit (still as an 'intact Group') for delivery to LA proper. Once in LA at the TOC facility, the individual carriers within the Group are independently de-modulated using a (lower) single sideband receiver, and the audio/data each contains is then plugged into a leased telco line or radio circuit that carries it to the final destination point.

Now in the case of our Chicago bound Supergroup, perhaps we end up with customers spread throughout the Chicago area. Let's say that by careful planning all of the satellite customers that have been bundled into the Supergroup-Group that is occupying spectrum in the 312 to 360 kHz portion of the Supergroup are in the Elmwood Park area of Chicago. At the Chicago receive site (which is out by Lake Geneva, in Wisconsin) it would be possible after demodulating from 4 GHz to baseband the particular transponder to selectively take that frequency range of baseband (312 to 360 kHz) and send it as a Group on its own terrestrial microwave or radio link to a distribution site serving Elmwood Park. Then at Elmwood Park the individual (12) carriers are demodulated to true-baseband (audio/data) and plugged into local loop telco leased lines for final delivery. At the same time other Groups within the Supergroup received at the Lake Geneva receive-terminal can be sent either to individual local distribution centers or into downtown Chicago for re-distribution via leased lines.

The beauty of all of this is the 'bundling' or 'packaging' that this approach allows. Rather than having to demodulate down to baseband audio (i.e. take the individual carriers to sound or data impulses) at **each** point, it only happens once; at the final distribution point just before it goes into a telco or radio link to the destination. Otherwise the signal is handled every step of the way at RF (radio frequencies) and these radio frequencies are bundled and batched and (block) converted around to get them into and out of the system as a group.

The Other Approach

As noted in the opening paragraphs, there are two approaches to sending less-wide-than video signals via satellite. We have just described the FDM-fm system which is by far the most common employed. There is another system as well.

Not every would-be satellite communicator is so located that he has ready access to a TOC or uplink site. For such a user just 'getting into' the system or 'receiving from' the system would involve a very healthy expenditure in terrestrial linking. A 100 mile private microwave hop for example could cost the would be user $100,000 and that just gets him into the system!

As the number of uplink sites grows (and this is one of the fastest growing areas in satellites these days) sooner or later virtually anybody will be within a reasonable-cost terrestrial distrance from an uplink. But sooner or later **may be** several decades. So to handle the interim problem a 'remotely located' satellite communicator has to install his own uplink site. He may in truth share it with several others in the same area but for now assume he is all alone. Now as a stand-alone single-channel requirement user, he doesn't need all of that fancy multiplexing gear. What he needs is some way to transmit a single channel of voice or data **into** the bird, and in turn if he is actually engaging in a two-way operation, get a single channel back. This is called the SCPC (for Single Channel Per Carrier) technique and the name says it all. SCPC is not as spectrum effective as the FDM-fm approach; it cuts by around 50% the number of 'circuits' that can be carried simultaneously through a single transponder. But it has the flexibility of being a stand-alone system. Using a relatively small uplink dish and relatively low power uplink transmitter (4.5 meter dish, perhaps as little as 30-100 watts of uplink power) the system can be installed quickly and put into operation in a few hours time.

The method of generating the signal (in the SSB format) is essentially the same with SCPC; and with some exceptions the signal will 'sound' the same to a listener as an FDM-fm signal. The exceptions are important however:

1) **Perhaps** the user cannot cram all of his input modulation data into a 300-3400 kHz bandwidth. OK - the SCPC approach can allow wider bandwidths and they may or

may not be 'recoverable' with a standard SSB receiver.

2)**The uplink** site may well not have the effective 'power-per-channel bandwidth' as a full FDM-fm uplink site; this can cause the signal going through the satellite to appear to be considerably weaker than the FDM-fm signals also going through the same transponder.

In practice, the SCPC carriers may well be operating in a portion of the transponder all by themselves although in theory they **can be** slotted in right next to the boundary of a Group or Supergroup or Mastergroup.

Multiple Inputs

One of the beauties of the satellite system is that it is not essential that all of the uplink signals going through a single transponder come from the same site. For example, it may be operationally desirable to load up a transponder so that there is a Group frequency band between 60 and 108 kHz originating at Lake Geneva, a Supergroup between 312 and 552 kHz originating at New York (Vernon Valley), a second Supergroup between 812 and 1052 originating at Atlanta and so on. Each uplink site transmits to the satellite its own bundle and each receives the alternate bundles destined for its area.

In the same way SCPC transmissions can be fitted in virtually anyplace that they will match the overall allocations scheme. Again, this is a very flexible (and quickly re-configured) system.

Receiving All Of This

OK - now you understand the basics of how the signals get put together, and are placed onto the bird. Now what happens at a downlink site?

First of all to recover these Groups, Supergroups and Mastergroups we let our standard TVRO receiver do its thing. It receives the 3.7-4.2 GHz range, downconverts to some IF (such as 70 MHz) and then this IF is demodulated to baseband (i.e. a spectrum from 0 to some upper frequency limit less than 10.75 MHz). Your TVRO receiver may well have a 'baseband output' jack which up until now you never considered using for anything except as a source of video to plug into either a TV monitor or a TV re-modulator.

However, when you tune your TVRO receiver to one of the non-video channels (say transponder 15 on FI) you are now demodulating (although it can't be seen on the TV screen since it is not a video modulation format) all of the data that is there. Since you now understand that some or all of the spectrum between 0.0 and a maximum of 10.75 MHz may well have individual carriers (in Groups, etc.) present, naturally you want to know how to make these carriers 'talk to you'.

Remember that even though we have 'demodulated' the 4 GHz signal with our TVRO receiver, the output of our TVRO receiver at this point is really still 'modulated'. Each of the carriers inside of the cable coming out of the receiver are still on descrete RF (frequencies) and each must be further demodulated from the typically single sideband format.

We do this by running a cable from the 'video/demodulated/baseband' output on our receiver to a receiver than can tune the spectrum of interest. That spectrum is from 0.0 MHz up to as much as 10.75 MHz. If you are familiar with Ham or other communications equipment, this is starting to sound like a communications receiver. It is.

The receiver that will perform the final demodulation is a selectable sideband tuneable receiver. There are dozens of different makes and models around, many of them on the used equipment market and selling for between $50 and $500. However, there are some warnings here:

1)**Most receivers built** for this application start off at 500 kHz (their 'bottom tuning frequency/range') and tune upwards to 30 MHz. The upper tuning limit is no problem; you aren't going above 8 or 9 MHz most of the time anyhow. But ideally you would like to tune **down to** at least 100 kHz.

2)**Not all** such receivers are SSB adapted; some (in fact many) were built years before SSB came along and they are AM (amplitude modulation) receivers with perhaps a BFO (beat frequency oscillator) thrown in for CW (continuous wave or Morse code) reception. You **can use** a BFO equipped receiver to tune in SSB or an older AM receiver but you won't like doing it very much because it is unstable, tricky, and generally not much fun.

3)**Some of** the more recent receivers only cover the Ham radio bands (i.e. 1.8-2.0 MHz, 3.5 to 4.0 MHz, etc.). This will give you a 'peak' at a portion of the spectrum, but not all of it.

Recently, a few of the popular (Japanese) shortwave communication gear manufacturers have come out with some very fine solid state receivers that tune from 100/200 kHz all the way to 30.0 MHz. One that works exceedingly well is the Kenwood R-1000 (it is designed to tune from 200 kHz to 30.0 MHz with full sensitivity, and down to 0.0 with reduced sensitivity). Priced in the just-under $500 class, it is available from any Kenwood dealer (one that deals in mail order is **Burghardt Amateur Center**, P. O. Box 73, Watertown, S.D. 57201; [605/886-7314]).

KENWOOD R-1000 RECEIVER makes excellent demodulator system for narrow band voice/data services.

So you hook up a SSB compatible receiver to the output of your TVRO receiver, at the baseband point. Then what?

Dial up a transponder with data (again, a good place to start is transponder 15 on SATCOM FI since we will assume you are already pointed at this bird!) and adjust the communications receiver to receive lower sideband. If you are capable of tuning 100/200 kHz up to 30 MHz with your receiver, just start dialing upwards from the 'low' end. Every 4 kHz or so (with some holes here and there which we'll discuss separately) you will hear a carrier. If it is not modulated at the moment, you'll hear an audio note in the 0-2 kHz region as you tune in and out of the carrier. When you run across one that is modulated at the moment, you'll hear a funny Donald Duck sounding voice which will 'clarify' (i.e. sound more normal) as you tune the signal in precisely.

Or you may hear something that sounds like a buzz saw. Or something that sounds like musical chimes. Or you may hear a telephone circuit ringing signal or a busy signal.

Using transponder 15 as an example, you can expect if you tune from the lowest carrier (around 100 kHz) to the highest (around 8433 kHz) to hear everything from telephone conversations to the latest Stock Market quotations, national radio network audio feeds to communication circuits between operators of such uplink sites as Vernon Valley and South Mountain. At any given moment you may find between 600 and 1200 separate carriers in place!

Variations

Since you are being introduced to a fascinating new world of very high quality narrow band communications, you will want to know and understand some of the variations to what you may encounter.

1)**Buzz** - that's the 30 hertz energy dispersal waveform. The audio/data transponders have the same requirement to 'spread' the signal within the transponder as

the video signals. This 30 kHz dispersal signal almost always occupies a 4-12 kHz wide space at the **bottom of a Group or Supergroup or Mastergroup**. You'll hear it... it just sits there and buzzes at you. When a transponder is heavily loaded with many FDM-fm carriers, the 30 kHz signal is backed off (the more carriers present, the less energy dispersal required since unlike video where the modulation is concentrated on a single carrier, with FDM-fm the modulation is already spread over many hundreds of descrete carriers evenly [more or less] spread through the RF spectrum anyhow).

2) **Musical Chimes** - This will be teletype or RTTY to be more precise. If you are familiar with amateur radio, you already know about such things. If you are not, here is what is happening. Letters and numbers are converted by a RTTY modulator to audio tones. Combinations of tones plus the length and space between tones creates a separate (distinct) code-group for each letter, number and punctuation mark in the English alphabet. At the transmit end a person or a machine types out a message on a keyboard. The series of code-group-tones leave the keyboard/modulator and end up via the Group/Supergroup routine on the satellite. When you tune across the RTTY modulated signal with your communications receiver you hear the series of tones that make up each character.

Guess what? Now you have to demodulate these tones (!). Yes, you have been through demodulation of the 4 GHz signal to baseband and then you went through demodulation of the SSB (AM) signal to audio and now you have to go through demodulation one more time! To do this you run a simple two-wire cable from the speaker jack (or headphone jack, etc.) on your communications receiver into yet another demodulator box; **an RTTY demodulator**. This demodulator interrogates the tone combinations and turns each into a character; a letter, a number or a punctuation mark. To this (RTTY) demodulator you connect some type of printer device; i.e. sort of like a free-wheeling typewriter that gets its input from the RTTY demodulator.

material received this way for later playback. Sources for such equipment? Round up a copy of any of the popular amateur radio magazines (**QST, CQ, 73, Ham Radio, Ham Radio Horizons**) and browse the advertisements.

We'll see who is sending RTTY traffic, and where, separately. Suffice to say that all of the major news services plus many private commercial and military groups use this 'message-mode' to transmit data via satellite.

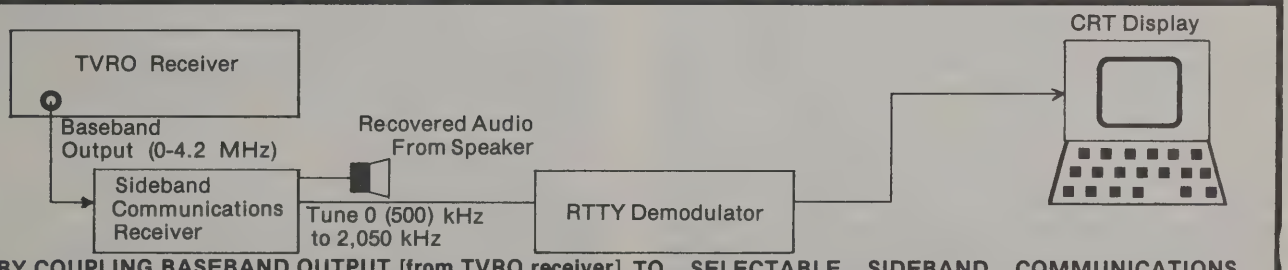
Private?

We said at the opening of this section we wouldn't talk about Section 605 and what it means; that his was an engineering study of what narrow band service on the birds is all about. We'll deviate from that slightly to talk about telephone message traffic.

There are thousands of telephone circuits on the birds. Some are pretty commercial; such as the 'block' of more than a dozen channels in use by the Holiday Inn Holidex 800-number reservation system. Others are just non-commercial, such as the private telco links out of remote Alaskan villages.

For years people have been tuning in overseas telephone circuits on shortwave (i.e. between 3 and 30 MHz) and on VHF (the mobile telephone circuits in the 160 MHz region). Common sense tells you that you are eavesdropping even if you don't understand the law (Section 605). We believe Section 605 will be clarified one day in the next few years and much of what is ill-understood and ill-enforced about it will become crystal clear. In the interim it is **our strong suggestion** that you employ good common sense when tuning in these circuits. There are hundreds of hours of amusement in just listening to somebody else's private telephone conversations but you should keep in mind that the mere act of listening is at the least a moral invasion of their right to privacy. Turn the shoe around on the other foot - would you want someone listening to your private telephone conversations? Anyone? The next time you make a long distance call you may be the subject of someone else's eavesdropping!

Oh yes...most (better than 99%) of all circuits are one-way per channel. That means you hear only a single side of the conversation. when the channel you are listening to is quiet



BY COUPLING BASEBAND OUTPUT [from TVRO receiver] TO SELECTABLE SIDEBAND COMMUNICATIONS RECEIVER, SSB-[FDM] AUDIO SIGNALS ARE RECOVERED.CONNECTING AUDIO OUTPUT OF COMMUNICATIONS RECEIVER TO RTTY DEMODULATOR PRODUCES NEWS/WIRE HARD [paper]OR SOFT [CRT] COPY DISPLAY.

There are two types of printers commonly available; one that prints out on paper and one that prints out on a cathode ray tube (CRT); more commonly known in this biz as a 'picture tube'. The paper printer feeds paper off of a long roll and with it you can have tens of hours of hard copy piling up while you are away doing something else. You can read it at your leisure. The CRT display will print out on the screen some maximum number of lines of printing at a time and then as the screen fills up the top line is bumped off the screen while a new line appears at the bottom.

As you may have guessed, we are starting to get into some bucks here. An RTTY demodulator can cost anywhere from $200 in a kit to over $1,000 as a commercial gadget; the printer can be from $50 on the surplus market (Model 28 and other machines from The Teletype Corporation® are sold as used items through various amateur radio outlets) to as much as $1500 for a super deluxe CRT package. With additional attachments you can audio-tape and store the information coming out of your communications receiver (on an inexpensive cassette recorder) and in this way preserve

that simply means the person who's side you are 'tapping' into is listening him or herself. For that small percentage where the audio is duplexed (i.e. both are audible to you) it may be apparent that you have two fairly widely separated levels of audio; at much as 30 dB between the loud one and the soft one. The fact that you hear both sides is a tip-off that **perhaps** (that means **maybe**) somebody in the satellite circuit is themselves listening to the conversation and they have some 'switches' thrown. OR - it could mean that you are on a 'double hop' channel where both sides have been duplexed at a common uplink terminal and then sent back out again on a transponder channel that is different than the two simplex (one way at a time) channels.

Connection Problems

Your present TVRO receiver may be so designed that what comes out of the 'baseband' output (where you plug in the communications receiver) is severely 'filtered' **above** the normal baseband **video** frequency range of 0 to 4.2 or so MHz. What does this mean? Well, to keep the normal aural sub-carriers associated with a video signal from getting into

the video display circuits (i.e. either a monitor or RF video modulator) the receiver designer has built in a filtering circuit that passes only the portion of baseband that is going to contain video information. This cross-over point can occur anyplace from 4.2 to 4.5 MHz. That means that anything **above** this filtering point is going to get 'chopped' out of the baseband output. That also means that any carriers modulated within the transponder above this filtering point are going to be severly attenuated or just eliminated.

What is the solution to this (if you run the system with the filtering in place you won't copy the data above the cut off frequency very well; limiting you to the region below approximately 4.2 MHz)? The best solution is to look into where in your receiver you can connect up an output line to drive the narrow band receiving equipment **ahead of that filter**. Some commercial receivers already have such an output jack available. After you locate the spot ahead of the filter, simply run a .001 disc ceramic capacitor from that point to a new (added) output jack and plug in the line to your communications receiver in the new jack.

The output of your TVRO receiver may be so strong that you will have to reduce the overall package gain of the communications receiver. The Kenwood R-1000 previously mentioned has a front panel switchable attenuator that lets you switch in 10 dB steps of attenuation. You'll know when there is too much 'signal gain' ahead of the communications receiver; if it is equipped with an 'S' (signal level) meter, the meter will indicate readings at the S9 mark or over, even when you are tuned between carriers (i.e. **no signal being received**).

As you tune between 100 kHz and the top end of the band you may notice that suddenly a whole group of signals can't be tuned in (i.e. clarified). Don't panic; the uplink transmitter has simply multiplexed this Group or Supergroup into the circuit 'upside down' and to tune them in **switch** the communications receiver **from** lower sideband **to** upper sideband. We'll talk more about this shortly.

One of the advantages to receiving narrow-band signals is that they do not require as strong a satellite receiver signal for good quality reception. Why is that? Well, whenever the 'bandwidth' (i.e. the amount of spectrum space required to transmit intelligence) is reduced, the whole system picks up additional sensitivity because you can employ a narrower (i.e. sharper) receiver to tune in the signals. For example, with a (big) 20 foot dish equipped with a 120 degree LNA and a standard receiver, these SSB signals typically measure signal to noise ratios in the 40 to 50 dB range. If you don't identify with numbers like this, trust us that these are good numbers indicating loud and clear reception. This is another way of saying that when you have a 'marginal' TVRO picture (one with noise in it or on the verge of noise) the audio SSB signals will **still be loud and clear** on a system as described here. In fact, **with a six foot dish equipped with a 120 degree LNA and the communications receiver system lash-up described here**, you can still get 'perfect' (i.e. noise free) audio or data reception.

In fact - the signals are so loud that when you are cross polarized (i.e. tuning in a vertically polarized transponder with the feed antenna oriented in a horizontal feed position) the signals are still good (if not perfect) copy on a 15 foot sized dish!

Receiver stability - an unstable TVRO receiver will be a problem. If your local oscillator stage (VCO) is not pretty stable and if your receiver AFC (automatic frequency control) system is not performing pretty well, you will shortly discover that you are 'following' the narrow banded signals all over the dial with the communications receiver. The solution may not be simple but it should be obvious; stabilize the receiver!

If your receiver has an AGC (automatic gain control) system, disable it before using the communications receiver for what follows:

a) **Your TVRO receiver seldom has an accurate signal level meter** indicator; one that tells you when you are making small improvements (or degradation) in the aiming of TVRO antenna. The communications receiver will typically have a good quality 'S' (signal level) meter on it.

b) **Having dis-abled the TVRO receiver AGC** (if there is one), tune in an unmodulated carrier with the communications receiver (using the RF gain control or a switchable front end pad such as the R-1000 employs) so that the carrier you have tuned in reads around 'S9'; typically mid-scale, or lower.

c) **Now**, as you adjust the TVRO antenna azimuth and elevation **watch the 'S' meter'** on the communications receiver. A rough rule of thumb is that for each 1 'S' unit you gain or lose on the communications receiver 'S meter' you have just picked up or lost 1.5 dB C + N to N (carrier plus noise to noise) at 4 GHz with your dish. In other words, since an 'S' unit is usually 6 dB ('S meters' are typically calibrated so that all of the 'S' marks from 0 to 9 are 6 dB steps while above 'S9' the meter is calibrated in 5 or 10 dB steps), 6 dB improvement in a 2.4 kHz bandwidth works out to around 1.5 dB change in the 4 GHz C + N to N ratio. As long as the carrier you are tuned into stays unmodulated, it will be an excellent 'test signal' for fine tweeking on your TVRO dish.

In other words, perhaps the only real 'justification' you need to add a communications receiver to your TVRO installation is the fact that you then have a very accurate 'metering system' with which to align your antenna to the various satellites!

Now when you are working with very weak signals (such as when you are first getting a system operational, or perhaps you are trying to make INTELSAT's feed for Brasil look good or even trying to tune in Russia's MOLNIYA as described in this Manual), you will find you can tell whether things are better or worse **much quicker** and with much **greater accuracy** with a communications receiver tuned to an unmodulated carrier on a transponder someplace. I have yet to find any satellite that doesn't have at least one audible (on a communications receiver) carrier on it if it is in the TV relay busines. These carriers are there for many purposes including providing telephone intercom links for the people operating the satellites. Since people don't communicate all of the time, when they aren't talking the steady unmodulated carrier is there for you to use in your measurements. I can tell you this - the first time you have your receiver on an unmodulated carrier on Russia's MOLNIYA and the carrier suddenly breaks off and a voice starts coming out of your speaker in Russian, you'll alternately panic and scream for everyone within a hundred miles to "come and listen to this Russian engineer!!!". It's quite a thrill.

So What's Up There?

Recall that if all of the present transponders on COMSTAR, SATCOM and WESTAR were fully loaded today with 4 kHz spaced 'channels' we would have more than one million seven hundred thousand separate channels active. However, in the real world we have 56 of the 158 'possible' transponders now in the sky assigned full or part time to video service and a few that are not suitable for any service (i.e. they are broken). A separate portion of this manual provides a look at **all** of the transponders in the sky.

So what about those transponders that are loaded down with SCPC and FDM-fm 4 kHz channels? What are they 'loaded' with?

We'll concentrate for illustrative purposes on the two SATCOM birds since once you understand the 'format's' being employed you can pretty well decipher what it is you run into on the other birds as well.

(1) **The SATCOM F1 Bird**

This is "the" cable TV bird. In other words, there's lots of video transponder activity but not a lot of non-video activity. What is there, however, is most interesting.

Video is on transponders 1, 2, 3, (4 is 'broken' although several observers report they suspect it is being used for SCPC on occasion; a rumor not substantiated), 5,6,7,8,9,10,11,12,13, 14,16,17,18,20,21,22,23 and 24. That leaves us with 15 and 19.

(2) **SATCOM F1 - Transponder 15**

This may be the 'most heavily loaded' non-video transponder in the sky today. It is very busy most of the time.

The assumption through all of what follows is that you have plugged a SSB (single sideband) communications

receiver into your baseband output on your TVRO receiver. This is nothing more than a simple (RG-59/U) cable connection; output of the TVRO receiver to the input of the communications receiver. Now you should be getting 'baseband' out of the TVRO receiver **before** the video low pass filter **if** you expect to find **all** of the data channels that in some cases extend up into the 8(+) MHz region on a heavily loaded transponder. TR 15 is one of those that goes up well beyond the typical 4.2/4.5 MHz "cut-off" you can expect to have if your communications receiver is connected to the TVRO receiver through the normal video output jack.

A) **The first carrier** you will find will be at **92** kHz (0.092 MHz). It will be unmodulated (a so-called AO carrier).

B) Then starting at 110 kHz up through 202 kHz you will find 'leased circuits'; the type in use by various private firms manufacturing electronic gear, heavy machinery, oil rigging equipment and so on, between one office and another office. You'll learn about shipping delays, competitive pressures, long lunches and last night's cocktail party. All of this block will be LSB (lower sideband). On **206** kHz you will discover one of those 'rare' situations where both sides of a (telco) circuit are audible on the same channel.

C) From 313 kHz through 481 kHz you'll find more (telco) circuits except this batch will be **USB** (upper sideband); to "clarify" them you'll have to **reset** your communications receiver to **upper sideband** and note that best voice clarity will occur on **odd** dial settings rather than **even** (as is the case with LSB signals).

D) From approximately 500 kHz through 1618 kHz you'll find several hundred more LSB telco circuits, an occasional buzz and some musical chimes. All LSB.

1) There's an interesting one at **1030** kHz; apparently an 'open bugging mike' in some public gathering place. No conjecture on who is bugging who and then transmitting the "bug's copy" via satellite to some long range monitoring point!

E) At **1622** kHz LSB you'll find lots of the latest stock market quotations late in the afternoon; a private stock market concern east coast to west coast link.

F) From **1634 kHz through 1690 kHz** you'll find 14 Holidex (Holiday Inn) reservation lines; all LSB. There is another group of Holidex outward bound lines in the 2182-2194 kHz region (i.e. 2182, 2186, 2190, 2194 kHz). One of these, 2186 kHz is used by Holiday Inn management types for personal and business calls. Yet more Holidex reservation lines are in the 4193-4205 kHz region on USB.

G) There is an example of an 800 number outward bound line, operated by the service department of a major computer supply firm, on **2230** kHz (LSB).

H) If you want to see how data bursts and voice are married, onto a single carrier, check out 3030 kHz (LSB). Or how VIP's are catered to, try 3182 kHz (LSB). Or a major oil company conducting its affairs, try 4329 kHz (USB).

There's a good example of an unassigned block (i.e. no carriers present) between 3842 (LSB runs to 3838 kHz) and 4154 (USB starts at 4157). Or there's a good example of a Supergroup bundle in the 6293-6553 kHz (USB) region; **the Chicago area is uplinked in this region.** USB continues through 7017 kHz and there's another example of both sides of a (telco) conversation on 7052 kHz (LSB).

This very busy transponder stays "busy" right up to 8433 (USB) kHz. Loading this heavy is unusual as we shall see.

This transponder is filled with voice communikcations; we've barely touched the surface here since 4 kHz by 4 kHz listings one after the other serve no really useful purpose except to fill pages; especially when very little of this is "public".

3) **SATCOM FI - Transponder 19**

RCA, we feel, has been less than truthful about the 'status' of **this** transponder. Back when Ted Turner was trying to force RCA to honor an agreement he said he had with them, for his recently activated Cable News Network (transponder 14), RCA was acting like Turner might just as easily end up on 19 as 14. Observations suggest 19 on FI is sick (very sick).

When you dial in a transponder through the communications receiver system outlined here, you'll immediately notice a 'noise level'. That noise level is simply the gain of your TVRO receiver times the noise figure of your system. On a reasonably decent communications receiver the "noise" coming out of your TVRO receive system may register as much as S9 to S9 plus 20 (dB)! That's why we earlier suggested you need some way to crank the RF gain back on the communications receiver or simply dial in some attenuation to cut back on package gain.

Except on transponder 19; where measurements indicates this transponder has an artifically high noise 'floor' between 34 and 52 dB greater than say transponder 15 (as measured in a 2.4 kHz bandwidth; in a 36 MHz bandwidth the 'noise' is much lower but still in the 'teens').

There **are** carriers on TR 19, but they are not far above the noise and they are not very interesting.

A] The first carrier you will find is unmodulated at 98 kHz (.098 MHz). There will be 4 kHz spaced (LSB) carriers all the way to 296 kHz and then a 'hole' (no carriers) to 317 kHz.

B) USB carriers are found between 317 and 453 kHz; some have telephone traffic on them but it is noisey.

C) There are carriers on a regular pattern up through 2000 kHz and then a big 'hole', with **the last audible carrier** located at 2536 kHz on this transponder.

Don't waste much time on transponder 19; there is simply not much there! So much for SATCOM FI; lot's of traffic (on 15) but not that much of a 'public nature'. Let's jump to a satellite where the reverse is true.

4) **The SATCOM F2 Bird**

This is the RCA satellite located at 119 degrees west. From the start of the first HBO telecast via satellite on September 30, 1975 until June of 1978 this was "the" cable television bird. Then RCA decided to shift all CATV traffic to FI because CATV traffic was growing very fast and RCA had designed F2 with a special coverage pattern for Alaska. This F2 coverage pattern precluded CATV from growing into use of at least 6 of the F2 transponders (the six boresighted on Alaska; see separate section of this manual).

F2 is basically a better 'looking' bird than FI. It has stronger ground level signals and is easier to find; especially in the northeastern states. Another section of this manual tells you what you can find in the way of video on this bird today. For here, we'll concentrate on the non-video transponder; the vertical set first.

5] **SATCOM F2 - Transponder 1**

This is really a 'reserve' video transponder, having been used in the past to pump video to Alaska, and for 'occasional' video feeds. However, you may find a single SCPC carrier on this transponder from time to time, on **369** kHz (USB). It will be very weak and if you can hear it your system is functioning very well (if you can't hear it, your system may also be functioning very well since it is not on full time!).

6) **SATCOM F2 - Transonder 3**

Years ago this transponder was utilized for carriage of the Alaskan Bush TV Network audio (the video runs on 23) plus for SCPC installations at various remote sites. The SCPC portion of the operation continues; and what you find on TR 3 are very weak level SCPC channels communicating with large (60-90 foot) antennas in Anchorage and elsewhere. Some of the 'louder' (this is relative since they are weak by comparison to other transponders) are on 719,902,959 (telemetering of a remote sensor), 1299, 4049, and 4286 kHz. In short, there's not much here to attract you except the challenge of testing your system sensitivity on 'weak' level carriers.

7) **SATCOM F2 - Transponder 5**

This one is a question mark. It is **either** used for occasional feed video or it is just plain 'dead' (transponders do 'die'!). Nothing here for the narrow band enthusiast in any event.

8) **SATCOM F2 - Transponder 7**

Here at last is 'paydirt'; Alaskan style. You can spend a day here or longer just getting acquainted!

A) The **first** active signal carrier will be found on **102** kHz (LSB) while by the time you get to 168 kHz you will find a military RTTY circuit (170 Hz shift). There is LSB

(telco) at 194-202 kHz and more military (LSB, 170 Hz shift) RTTY at 234 kHz.

B) Then there is something they call '**The Alaskan Forces Satellite Network**'; sort of a cross between Top-40 radio and Middle-Of-The-Road radio, put together especially for American Forces personnel scattered throughout the Alaskan 'outback'. You'll find the first one of these at 294 kHz (LSB) and it's there 24 hours per day.

C) There's more LSB RTTY (170 Hz as is most of the satellite stuff) at 328 kHz; followed at **333** kHz by Anchorage radio station **KBYR**. AT 353, 369, 385, 413, 417, 457 and 461 kHz there's USB (telco) circuits.

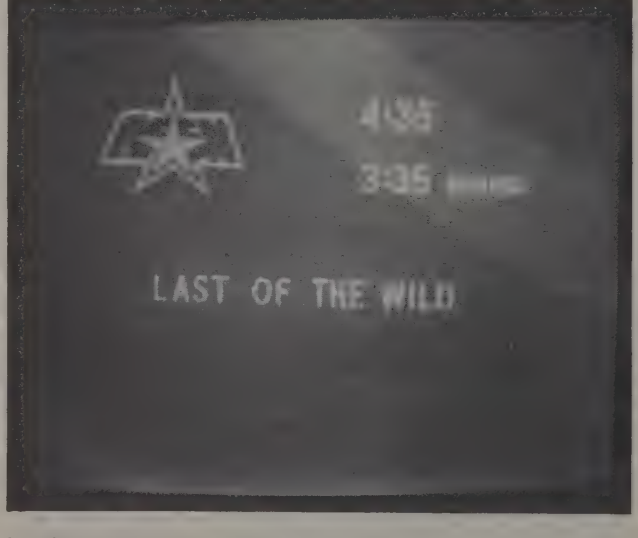
D) At **393** kHz USB you'll find Anchorage radio station **KYAK** which is a country and western station. At 450 kHz you'll find another RTTY/170 Hz shift/USB signal.

E) Carriers every 4 kHz follow, much of it telco circuits although at **958** kHz (LSB) you'll find a **'Soul'** radio program channel and up at 1173 kHz you discover yet another RTTY circuit. At 1190 kHz (LSB) there's another Alaskan Forces Satellite Network (AFSN) channel, more 4 kHz telco circuits and then RTTY at 1268 kHz (170 Hz shift again).

F) Through the 'teens' (1300 to 2000) you'll find much more telco plus **Mutual Radio Network** on **1702** kHz (LSB). If you are into aircraft weather, and flight operations, at **1938** kHz you'll find the **Anchorage airport control tower** while at **1946** kHz (LSB) you find **Kenai Flight Service Weather** (at 15 minutes past each hour, an extensive weather summary and forecast for all of Alaska).

G) At 2246 kHz you'll find more RTTY, one of the **ABC Radio Network** news feeds on **2358** kHz (LSB), the AFSN again at 3198 kHz. While the last regular carrier on transponder 7 is at 3282 kHz you'll find a private intercom line between the Anchorage control center for Alaskan satellite communications and some of the 'Bush Terminal receiving/transmitting sites on **3246** kHz'. They trouble shoot remote site break downs via satellite here!

Oh yes; if you want some fascinating listening, tune in one of the Anchorage (AM) radio stations, relayed via satellite (as listed for transponder 7 and 11 here). Not only is it 'cold' up there but if the local news reports are any indication, Alaska is still a pretty rough place to get along!



ALASKAN FORCES SATELLITE NET - on transponder 9 of F2 carries TV programs around 14 hours per day to military personnel in Alaska and elsewhere.

9) **SATCOM F2 - Transponder 11**

Transponder 11, like 7, is a fun place to tune around.

A) The first carrier is at **102** kHz. If coded cyphers interest or challenge you, try 118 (LSB). On **134** kHz there's one of the **National Public Radio** (NPR) audio channels (see, you don't need to go to WESTAR for NPR afterall!). On **138** kHz is a special channel where the remote offices of Alaskan legislators, away from Juneau (the state capitol) can send message back 'home'; you can hear both 'sides' of this one (i.e. it is duplexed).

B) On 214 kHz is another (duplicate) AFSN audio channel. On **230** kHz is a special duplexed channel which connects the Alaskan Fisheries Commission offices to the headquarters in Juneau. If knowing where the Salmon are running or which Bay is still iced over interests you, here's where to listen in! An RTTY link on 248 is good copy (LSB). There are USB telco links spread from 381 to into the 500's and another national radio network news feed on 598 kHz (LSB).

C) Yet a second **National Public Radio** (NPR) audio channel is found on **602** kHz (LSB) while on 680 kHz you'll find an RTTY that (170 Hz shift) which delights in sending coded messages. LSB telco is scattered from 690 kHz through 1178 kHz with repeat of the 134 kHz NPR feed on 814 kHz, 'internal RCA Alascom' maintenance channel communications on **946** kHz and coded cypher RTTY on 1138 kHz. On 1182 kHz there's another repeat of the AFSN service.

D) On 1208 kHz (LSB, 170 Hz shift) is another coded RTTY channel followed on **1234** kHz by **Anchorage Flight Center** communications. The usual mixture of telco channels follow at 4 kHz intervals until you run into 'enroute' Anchorage Flight Control traffic on **1498** kHz. Two AFSN channels are on 1502 and 1562 kHz. Between 1600 kHz and 2000 kHz are several substantial 'holes' with no carriers present.

E) At 2208 kHz there is an RTTY machine that likes to send the letter 'V' over and over (and over). On **2366** kHz you'll find the **Valdez** (Alaska) **Weather Advisory Service** which includes excellent analysis of the weather patterns all over Alaska including that coming east from the Bering Sea and Russia. Another RTTY machine (this one likes to send the letter 'M' over and over) is at 2470 kHz (LSB, 170 Hz shift). Yet another RTTY, this one talks in cyphers, is at 2518 kHz. On 2522 kHz you have Anchorage radio station **KBYR** but it is often 'jammed' by a 2 kHz heterodyne from a nearby mixing carrier.

F) On 2686 kHz you can hear remote Alaskan medical centers getting 'remote' (via satellite) instructions in health care. This is followed by numerous 4 kHz telco circuits until you reach 2754 kHz and another AFSN channel. Anchorage **KBYR** appears again on 2802 kHz but during the Alaskan nighttime hours you'll hear a special Christian radio programming channel here. On 2854 kHz you'll find Anchorage (AM) radio station **KFQD**. The last audible carrier on transponder 11 is found on 3346 kHz.

As you can tell, a person could become an 'expert on Alaska' simply by tuning around transponder 7 and 11 on SATCOM F2!

10) **SATCOM F2 - Transponder 17**

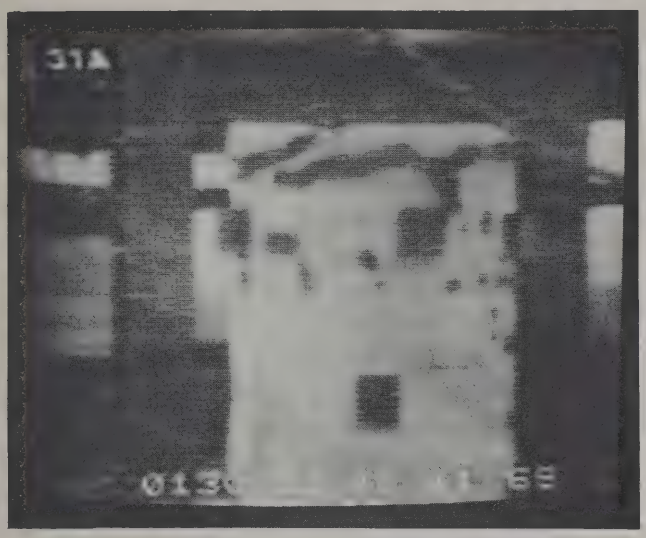
Perhaps you noticed we skipped over 13; check the 'SATCOM F2 Video Services' (page 33) of this manual. Transponder 15 is either dead or inactive while 17 is not very exciting, apparently in use primarily for SCPC communications. The first carrier is at 162 kHz with others in the 2124 kHz region, the loudest one at 2208 kHz and a fair number between 3538 and 3678 kHz. The 3678 kHz carrier is the last one in operation on the transponder. Most are unmodulated much of the time.

11) **SATCOM F2 - Transponder 19**

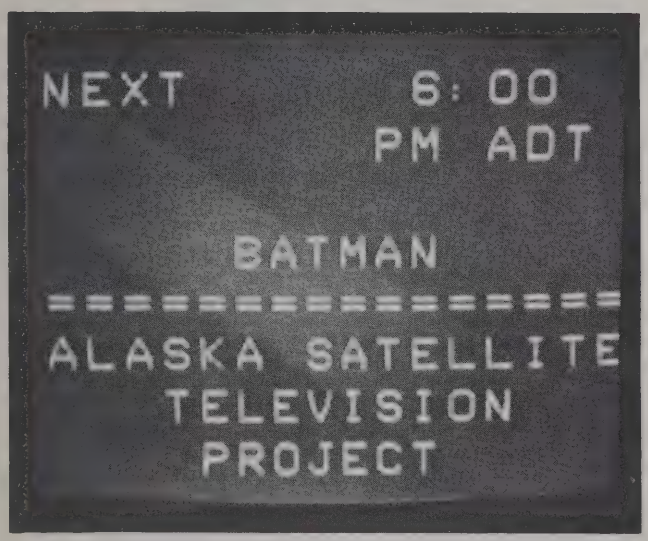
Even less here. The first (very weak) carrier is at 566 kHz while there is 30 Hz energy dispersal signal centered on 614 kHz.

12) **SATCOM F2 - Transponder 21**

And no more here; a weak carrier at 3498 and another at 3546 barely stick out of the noise.



NASA leases use of F2 transponder 13 to send video [Shuttle test sequence seen here] and data from Alabama and Texas to various monitoring locations. Signals are weak because of non-saturated or backed-off operating format.



ALASKAN SATELLITE PROJECT uses F2 transponder 23 for relay of television programming to 'Bush Terminals' throughout Alaska.

By now you should be getting the hang of transponder use for narrow band services. So in the interest of not boring you to death with endless lists of what is in use for what, we'll run through the **horizontal transponders** on F2 by noting just the general activity and point out special situations.

13) **SATCOM F2 - Transponder 2**

The first carrier is at 92 kHz while the last is 4394 kHz. There's RTTY on 403 kHz, a precise 1-tick-per-second 'timing circuit' on 1090 (LSB) kHz and lots of telco circuits. At the top end there is lots of energy dispersal signals.

14) **SATCOM F2 - Transponder 4**

The first carrier is on 92 kHz (see a pattern here?) and the last or top one is at 4390 kHz. **CBS Radio Sports** feeds are on 421 (USB) while **NBC Radio News** is on 469 (USB). Both of these circuits send material at random times, not full time. On 2128 and 2206 kHz there's RTTY circuits; 2128 likes to send the letter V and 2206 sends coded number groups. Both are **850 Hz shift**. On 2170 LSB there's a duplexed link (voice) 'of interest'. A strong 30 Hz energy dispersal signal centered on 2802 is a good marker and traffic above that point is thin.

15) **SATCOM F2 - Transponder 6**

The first carrier is on 102 kHz while the last is on 3082 kHz. Very loud unmodulated carriers (AO) are found at 200, 246 and 296 kHz. There's a 'hole' from 300 to 566. Anchorage telco circuits are in the 1478 kHz region (LSB); there's some unusual sounds at 1008 and 2956 kHz.

16) **SATCOM F2 - Transponder 10**

Again, in case you noticed, transponder 8 is missing; used by NBC TV. On transponder 10 the first carrier is at 94 kHz and the last one is at 4022 kHz. There's RTTY at 214 kHz sending numbers, a duplex Juneau circuit on 778 kHz and **AP Radio** is on 950 kHz with radio feeds (it is not on full time; about 50% of the time). Another RTTY circuit on 1134 (LSB), **Mutual Radio Net** feeds on 1354 kHz and 2082. Another duplexed (telco) circuit on 2142 kHz and another on 3554 and 3582 kHz.

17) **SATCOM F2 - Transponder 14**

If you noticed, transponder 12 on this bird is reported by RCA to be 'dead'. And transponder 14 is little better; one carrier at 843 kHz modulated with a 2 kHz tone.

18) **SATCOM F2 - Transponder 16**

This transponder has been variously reported as '**the** transponder' in the circuit that has the widest variety of useful narrow band traffic on it. It is a busy transponder, but it is not all that desirable.

The lowest carrier is found at 114 kHz while the highest is found at 8430 kHz. That makes the loading pretty close to transponder 16 over on F1. On **166** kHz you'll find the **AFSN** network. On 238 kHz (LSB) you'll find the **CBS Radio Network** news feeds; they turn off this carrier when it is not in use. At 310 kHz you'll find sports feeds but at a weak level. On 552 kHz you'll find Philadelphia radio station **KYW**. On 682 kHz you'll find the **UPI Audio News Service** (they call these 'actualities' and they feed dozens, sometime as many as 100, brief audio reports to back up the day's news stories). On 694 kHz you'll find **NBC Radio News**. On 700 kHz is the **AP Radio Network** (actualities). If listening to a telco 'busy signal' turns you on, try 1182 kHz or 1414. Above this region you'll find lots of telco circuits to the end at 8430 kHz.

19) **SATCOM F2 - Transponder 18**

The first carrier on this transponder is at 166 kHz and it is AFSN. There is high speed facsimile (FAX) on 668 and 874 kHz. Above this to 2782 or so is lots of telco circuits. An RTTY channel is on 2818 kHz while it is 'empty' from 3000 to 3538. The last carrier on 18 is at 3718 kHz.

20) **SATCOM F2 - Transponder 20**

The first carrier here is at 190 kHz and it is **NBC Sports**. RTTY circuits are on 674, 722 and 740 kHz. There's a 'hole' between 1550 and 1804 with plenty of telco circuits below 1550. There are other 'holes' between 2688 and 2734, 2886 and 2934, 3294 and 3334, 4250 and 4392 but plenty of telco and unmodulated carriers right up to the last regular carrier at 7636 (a **lone** carrier at 8432 is above them all). One 'special circuit' is found on **7381** (USB); a channel utilized by **NBC TV** crews out in the field communicating back to NBC 'BOC' (**Broadcast Operations Control**) during such events as golf matches, baseball games and so on. You will find this audio circuit in use when transponder 8 (F2) is being used to relay remote video feeds back to BOC.

21) **SATCOM F2 - Transponder 24**

Again we have skipped a transponder (22), which carries video. Transponder 24 is fairly lightly loaded; the first carrier is at 102 kHz and the last is at 1794 kHz. There is an RTTY signal at 214 kHz and plenty of Alaskan originated telco circuits in the full region up through 298 kHz with a hole to 574 kHz followed by more telco circuits to 1794 kHz. Many of the circuits originate in Juneau on this transponder with particular attention to the 1618 kHz spot.

As you can see, there is plenty of 'activity' on just this one satellite even though the satellite business is in an infant state of evolving.

THOSE INTERNATIONAL SATELLITES

From the vantage point of the United States/Canada, 'our' domestic satellites are the WESTAR/COMSTAR/SATCOM and ANIK series. To North American users of this Manual, all other satellites are 'international' and that includes for the moment the Indonesian PALAPA (semi-domestic), the INTELSAT (IV, IV-A and the new V series)and the two Russian systems MOLNIYA and GHORIZONT.

In this section of the manual we'll deal with what you have to know and do to 'access' these to-us international satellites. PALAPA is easy to deal with; you can't receive either of these two birds in North America simply because they are so far west that they are not visible to us.

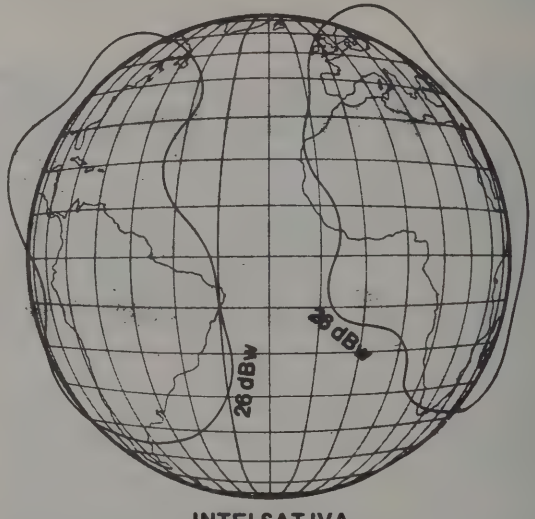
The visibility problem is important to understand. From the satellite's location in geostationary/Clarke orbit it has the capability of 'seeing' (as in line-of-sight) approximately 40% of the earth. If a satellite is designed to send signal(s) to all of the earth it can 'see' we say that it is operating on a **'Global'** beam (antenna) pattern. The shape of the Global beam pattern is essentially an oval; it extends from the equator due north to roughly the 80th parallel and due south to the same parallel; and it extends east and west of the over-equator longitude and latitude coordinates roughly 80 degrees due east and 80 degrees due west in longitude. We show a typical such coverage pattern here. It is important to understand that the earth is roughly a round ball and that because it is constantly being 'shaped' in both longitude and latitude in two basic directions at once (i.e. north and south and east and west) that the on-ground coverage area of a satellite operating with a Global pattern is not a rectangle/square but rather an oval. As you look at the diagram here you can see that the greatest distance covered north (and south) is along a longitude line that is **due north** (and south) of the satellite's location above the equator. The oval coverage area in the drawing clearly shows what happens as you move east or west of the satellite's longitude and then proceed north or south of the equator.

Anyone seriously interested in location satellites in either domestic or international service should begin by having on hand a computer created print out which shows the 'visible portion' of the geostationary/Clarke orbit belt available from any given set (your set)of longitude and latitude coordinates in the world. Several sources for such 'print-outs' are given here [1]. The 'art' of navigating your terminal antenna to the proper elevation and azimuth headings for your specific location is detailed very nicely in the STT Manual entitled 'The Satellite Navigator' (authored by Stephen Gibson;2).

The designer of an 'international' satellite has several coverage options open. He can elect a Global beam antenna pattern, a **Hemisperic** beam antenna pattern or a **Spotbeam** antenna pattern. The Global beam pattern is obvious and was just explanined. The Hemispheric pattern is shown in diagram form here. What you basically have with the Hemispheric pattern is a choice (by design or operational control) of eliminating all signal coverage either to the east, or to the west of the satellite's location. In doing this the signal strength level 'left' after electing one or the other 'hemispheres' is increased in signal level over what the same satellite would provide in the Global Beam pattern. Why? Simply because the transmitter power on the satellite is fixed at some maximun amount; when that power is used to cover all of the visible earth (i.e. Global pattern) the power must be shared with an area twice as large as when the same power is used to 'illuminate' only 50% of the 'visible earth' This says, quite correctly, that if you happen to be looking for a satellite with a Hemispheric beam that points **into your portion** of its coverage pattern, you can expect to find it considerably stronger than the same satellite would be in a Global pattern; actually, around 4 dB stronger in most instances.

The final choice for the satellite designer is a Spot beam pattern. For all practical purposes, a 'Spot Beam' pattern is what we have employed here in North America by our WESTAR/COMSTAR/SATCOM/ANIK series birds. By design, they are 'focusing' all of the available satellite energy

INTELSAT IVA
HEMISPHERIC BEAMS
(Indian Ocean Satellite at 60°E)



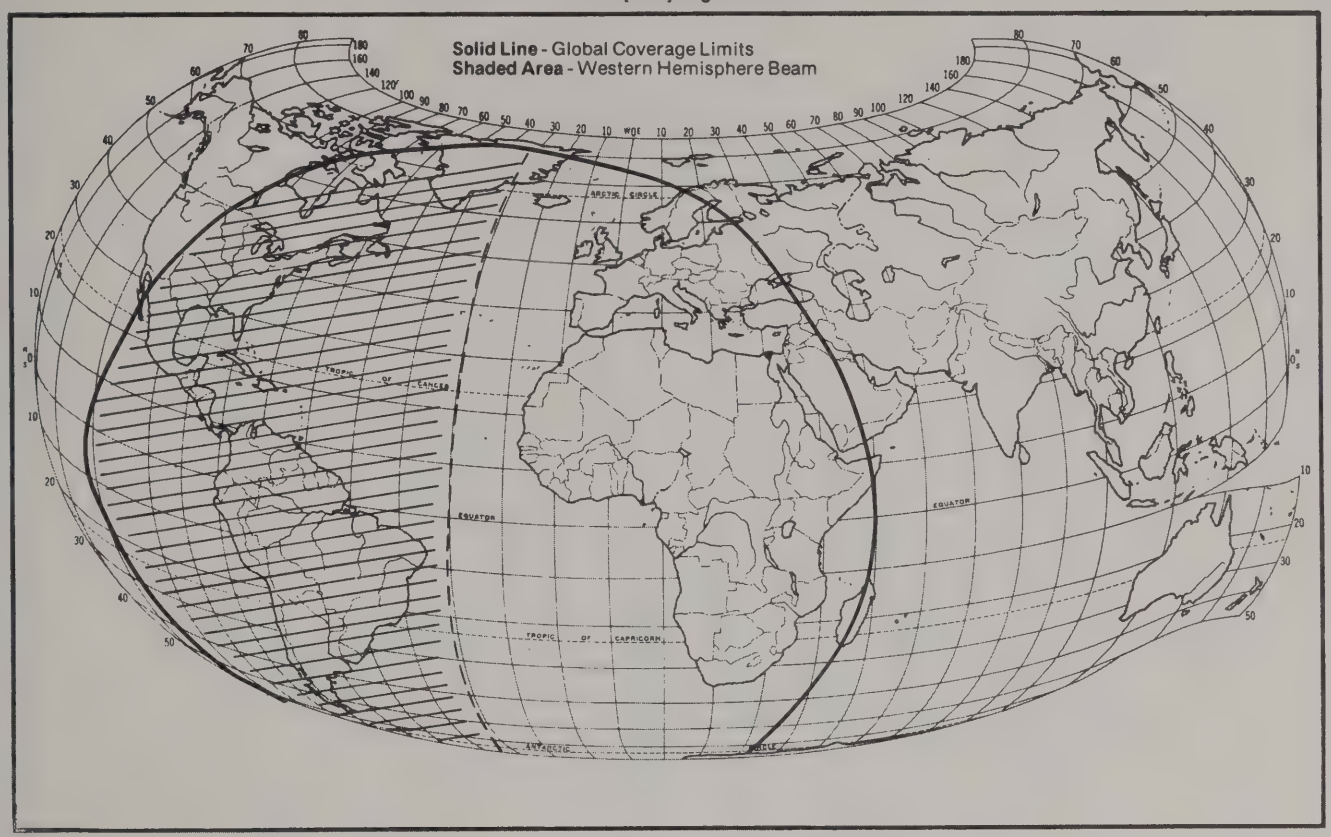
INTELSAT IVA
HEMISPHERIC BEAMS
(Atlantic Primary Satellite at 24.6°W)

---

[1]Here are three sources for a computer generated print-outs showing the azimuth and elevation settings for your location. In each case provide the service selected with your geographic coordinates [longitude and latitude to the nearest degrees, minutes; usually available from courthouse, local airport]. [a]Ronald Waltner, **353 North Kenyon, Indianapolis, Indiana 46219, price is $2.00; [b]** Richcraft Engineering, Ltd., **Drawer 1065, Chautaqua, N.Y. 14722, price is $7.50; [c]** William D. Johnston, **1808 Pomona Drive, Las Cruces, N.M. 88001, price is $2.00.**

[2] 'The Satellite Navigator' by Stephen Gibson is an STT manual which describes how the TVRO terminal antenna mounting system is designed and operated. It includes a complete treatment of correctly determining you elevation and azimuth angles, and a wide variety of antenna mounting systems including a home-computer operated system [and program] that automatically moves your antenna from satellite to satellite on keyboard command. Order 'The Satellite Navigator' at $30 postage paid (USA, Canada, Mexico) from **STT, P.O. Box G, Arcadia, OK, 73007.**

INTELSAT IVA-FI - 24.5 [25.5] Degrees West

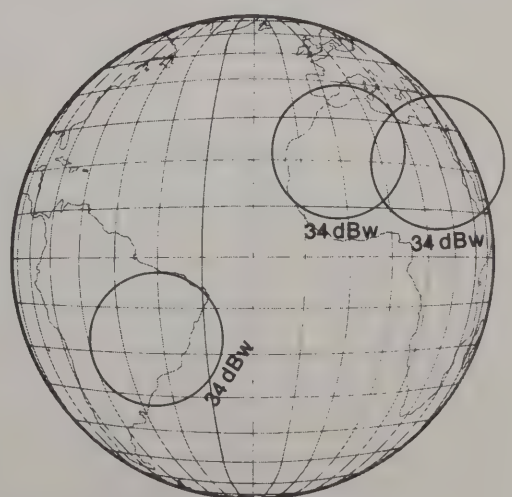


into one (relatively speaking) small area. The **transmitter power** on board the satellite is typically no more then that available with the international satellites; they gain their added 'strength' on the ground simply because they design the satellites to focus the available power into a smaller area of the earth. A Spotbeam on an international satellite is good news if you happen to be located in the region where the spotbeam is concentrated; it is bad news if you happen to be located outside of that area!

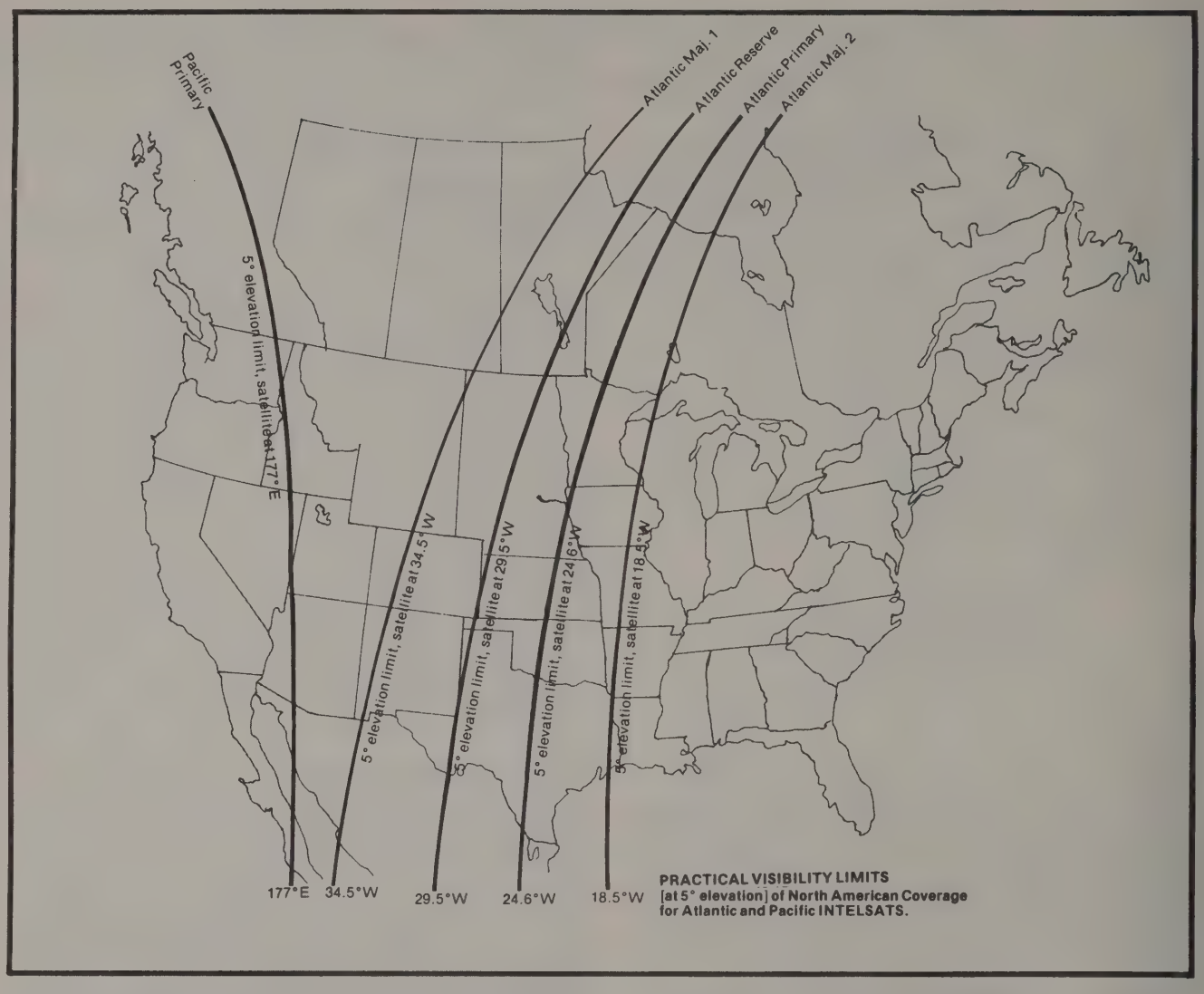
(1)**Global Beam** - Covers a wide area of the earth, but very Uniformly. On the INTELSAT family of satellites, such global beams are typically + 22 dBw signal level maximum (i.e. so-called saturated operating condition).On the Russian MOLNIYA and GHORIZONT family of satellites, typical EIRP levels are + 26 dBw (saturated) with INTELSAT and + 33 dBw with GHORIZONT. If you are in the illuminated hemisphere, you are in good shape. If you are in the non-illuminated hemisphere, you won't even know the satellite is 'on the air'.

(3)**Spot Beam** - Most international satellites have the ability to switch into a spot beam pattern but most use this pattern very sparingly. A table here lists some of the known potential spot beams but in years of satellite looking you may never see one in actual operation in the 3.7 to 4.2 GHz region. Spot beam levels are in the 34 dBw region for INTELSAT and 39 dBw for the GHORIZONT birds.

All international satellites are extremely 'power budget conscious'. That means the uplink power to the satellite is adjusted (up and down) to match the receive system sensitivity on the designated receive terminal(s). For example, when an uplink is working into a huge 90 foot receive antenna at the downlink site,the uplink power is 'backed off' to some power level which will provide an adequate signal level at the intended receive site. Obviously if the power is backed off on the uplink so that the signal is 'out of the sparklies' at a 90 foot receive antenna, a small 13 foot receive antenna would barely even know the downlink signal was present. Thus the true meaning of the phrase 'saturated'. It translates to 'maximum power output from the satellite'. On some Global beam transmissions, where in theory a + 22 dBw EIRP is possible, the actual operating output power may be as low as 16 or 17 dBw; clearly far to weak to 'access' with a small terminal. The same 'power conscious approach' is also applicable to some of the Hemispheric patterns although most of the hemi beams are run at close to the saturated (maximum) power levels available because of the type of receiving terminals in use. It is



INTELSAT IV TYPE SPOT BEAMS
(Possible footprints from Atlantic Satellite)



PRACTICAL VISIBILITY LIMITS [at 5° elevation] of North American Coverage for Atlantic and Pacific INTELSATS.

important to remember that with any INTELSAT (and to some extent any GHORIZONT although it is less likely here) system, the EIRP or 'footprint' power level on the ground can vary downwards from the maximun values possible and that adjustments are often made on a per-event-feed basis to reflect the receiving system sensitivity on the opposite end from the uplink station.

This tends to be confusing to the satellite receive terminal operator accustomed to predictable (and dependable as in full time) set-level EIRPs from the domestic satellites. While in theory the domestic satellites can also adjust their uplink powers to compensate for the sensitivity of the intended receiver sites, it is seldom done except in very special cases.

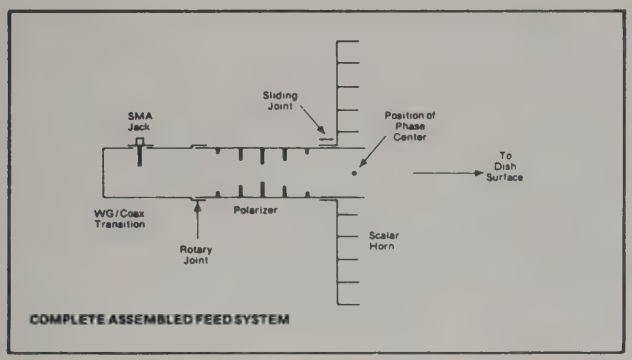
The bottom line or conclusion from all of this? Watching the international satellites can be more of a challenge than watching domestic satellites. You may even find high signal levels one day on a specific transponder and then very weak signal the next day on the same transponder!

(4)**INTELSAT standards** - Reception from INTELSAT satellites, the three user-optional antenna pattern configurations aside, requires no major adaptations to the typical small antenna terminal. In tests run during SPTS '80 Miame in February of 1980 and subsequently by private terminal operators, it was found that antennea as small as 13 foot in diameter equipped with 120 degree LNA and a typical home-type PLL (phase lock loop demodulator (receiver and produce watchable if not high grade video.

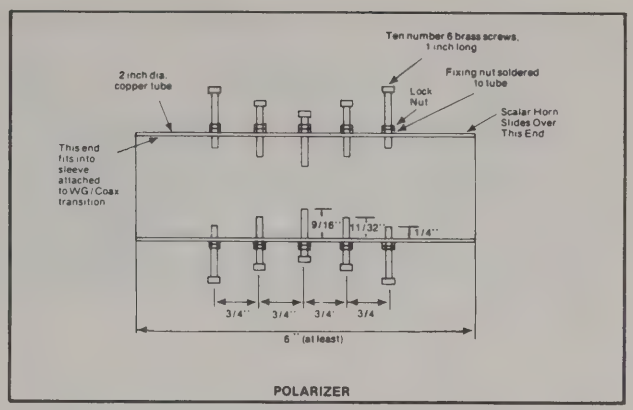
Here is what you can **change to improve** the relatively weak grade reception you will achieve by simply pointing your present domestic grade antenna system at the appropriate point in the sky for INTELSAT reception:

A)**Antenna Feed** - Your domestic grade terminal is equipped with something called a 'linear' feed antenna. This is a pick-up or probe device inserted inside of your LNA or feed system which responds to a signal which is aligned in polarization to the polarization of the incoming satellite TV signal. Domestic satellites such as ANIK and WESTAR (and Indonesia's PALAPA) employ something called 'linear-horizontal' polarization)i.e. directed) left and right as a more or less straight line parallel to your horizon (see separate section this manual on antenna polarization). Other domestic satellites such as COMSTAR and SATCOM employ two different sets of polarizations simultaneously; the 'linear-horizontal' and the opposite polarization called 'linear-vertical'; the latter's incoming waveform is up and down, or perpendicular to the earth.

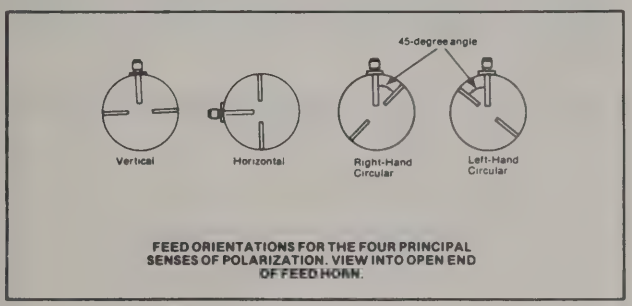
The INTELSAT and GHORIZONT and MOLNIYA satellites presently employ something called 'right-hand-circular' polarization. That means the signal coming your way from the satellite has not a parallel (horizontal) or perpedicular (vertical) format but rather it would look something like a giant



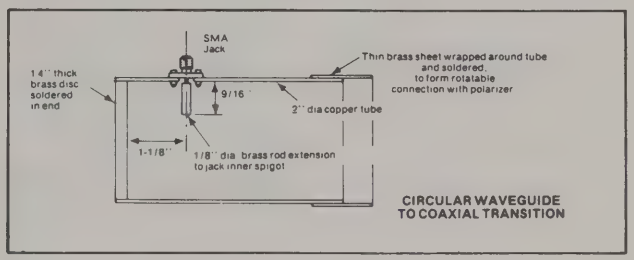
COMPLETE ASSEMBLED FEED SYSTEM



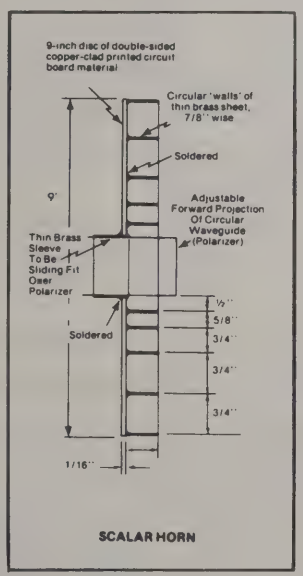
POLARIZER



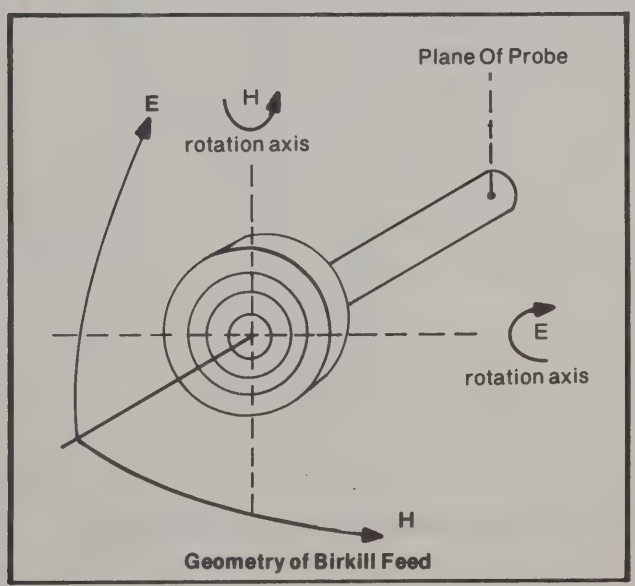
FEED ORIENTATIONS FOR THE FOUR PRINCIPAL SENSES OF POLARIZATION. VIEW INTO OPEN END OF FEED HORN.


SMA Jack
Thin brass sheet wrapped around tube and soldered, to form rotatable connection with polarizer
1/4" thick brass disc soldered in end
9/16"
2" dia copper tube
1-1/8"
1/8" dia brass rod extension to jack inner spigot

CIRCULAR WAVEGUIDE TO COAXIAL TRANSITION



SCALAR HORN



Geometry of Birkill Feed

cork-screw. The signal as it travels towards you is twisting constantly as it moves; cutting a cork-screw style 'path' through the air as it comes to you.

Now, if you attempt to receive such a circular polarized wave with a linear-horizontal or linear-vertical feed probe on your antenna, you will capture or collect only that portion of the circular signal which corresponds to your linear probe. It works out that you capture or receive about 50% of the actual available energy; you simply lose or don't 'capture' the 50% that is at that instant in the opposite polarization on the remainder of the cork-screw wave front. In technical terms, you are losing 3 dB (50% of the signal voltage) simply because your feed probe is not aligned with the full incoming wavefront.

In effect, you are diminishing the 'size' of your receiving terminal by 3 dB. For example, if your antenna is a 13 footer and you are employing a linear polarized feed to receive a (right hand) circular wavefront, your antenna is working as if it were not 13 foot in size but as if it were '3 dB smaller'; roughly an 8 foot antenna. Since the international satellites typically have quite weak signals anyhow (from +26 dBw on the hemi pattern for INTELSAT to +34 dBw on the GHORIZONT or MOLNIYA birds), to give up 3 dB of that EIRP by trying to receive the signals on a linear feed seems quite a waste up potential system sensitivity. In effect, by losing that 3 dB you are in effect looking not at a +26 to +34 dBw signal; you are looking at a +23 or +31 dBw signal!

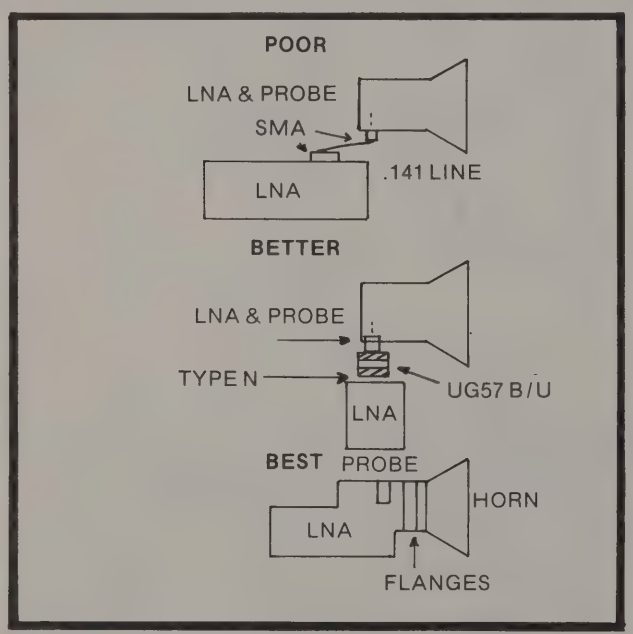
The solution to this is to install for international reception a **circular polarized feed** antenna; one that is designed to capture all of the available signal from the (right hand) circular wave front coming to your dish antenna. The most popular such feed antenna design was one created by English experimenter Steve Birkill of Sheffield, England. This is called a '**hybrid-mode**' feed and it has the ability of being user-field-adjusted to respond to **any of four** different types of wave front polarization that might be present, including: (1)

right-hand circular, [2] left hand circular, [3] linear-vertical, or, [:4] linear-horizontal.

There are two problems associated with this feed. Number one, they are not in commercial manufacture so if you want one, you have to build it yourself! Number two, this feed is designed with a probe in such a way that you cannot bolt the feed directly to an LNA.

Building it yourself is no impossible task; it requires some sheet brass or copper, a 200 watt or larger soldering tool, and about two to four hours of your time. Plans for same are presented here. This antenna design, by the way, has been built and measured at Stanford University's antenna test range and has been found to be an exceptionally efficent feed system. Even for regular linear vertical or linear horizontal reception it is an outstanding performer.

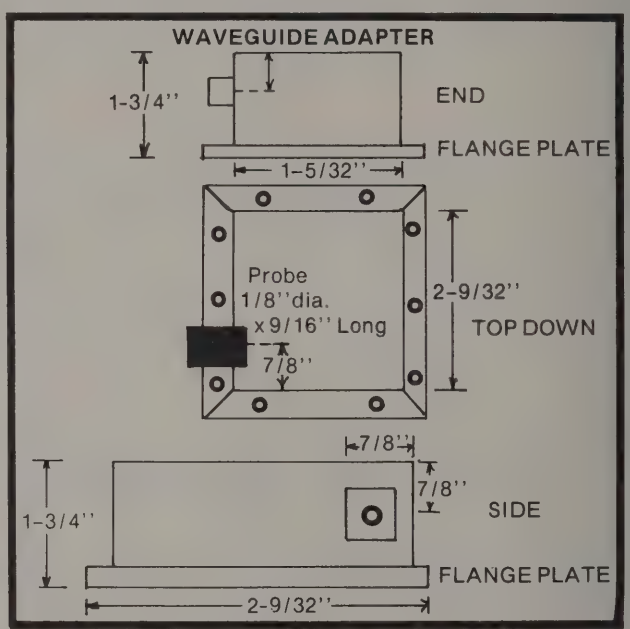
There are some warnings here. ANY length of coaxial cable, between the Hybrid Mode coaxial connector (its' output) and the adapter coaxial connector will lose signal. One solution is to use no cable at all; locate an **Amphenol UG 57B/U** male to male type N fitting which directly connects the Hybrid Mode mounted female connector to the adapter mounted female connector. You will still lose some signal here (perhaps 0.1 dB) but it is far better than even a couple of feet of coaxial cable. The adapter that bolts (flange-to-flange) to the LNA should be carefully constructed following the drawings here; it should have smooth internal finishing (no burrs or unsoldered gaps) and the flange-to-flange fit should be smooth and tight.



When you get all done with this adaption process, between the UG 57B/U fitting and just plain inefficencies of the system you will lose perhaps 0.5 dB of the circular signal. Thus you cannot realize the full 3 dB **improvement** with this method over the straight linear feed, but the 2.5 dB or so you will pick up can make a dramatic difference none the less.

B) **Receiver/IF Adjustment** - The INTELSAT feeds utilize something called 1/2 transponder format. That means that rather than utilizing the full 36 MHz bandwidth of a transponder for video, the INTELSAT video feeds are typically purposefully narrowed to 17.5 MHz wide. The impact of this on your small terminal receive system is that if you tune in such signals with a standard receiver (one designed for regular DOMSAT - domestic satellite - reception) you will be operating at reduced receiver efficency. The trick is to re-adjust your receiver for the particular 17.5 MHz bandwidth of the INTELSAT service(s).

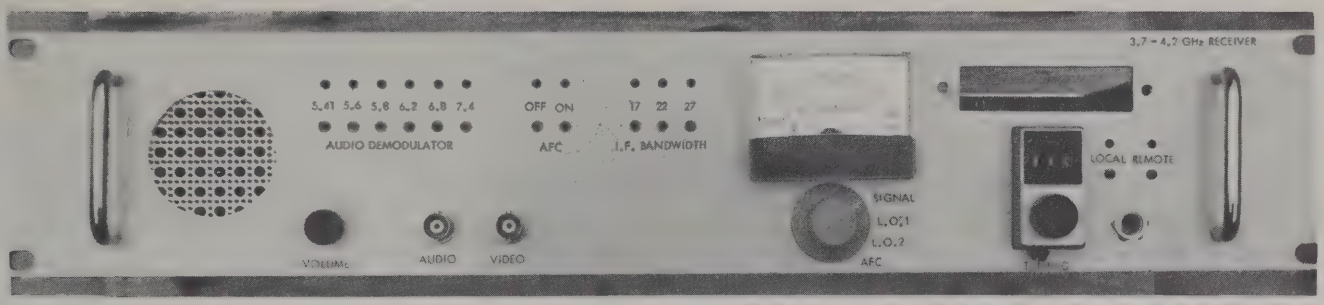
At the moment the receiver suppliers will equip your receiver on an **either** basis; that is, either for DOMSAT **or** INTELSAT. A technically competent person could go into his receiver with the proper test equipment and re-align the receiver IF bandpass filter section from the normal 26-30 MHz wide IF to one that is more suited to the 17.5 MHZ IF bandwidth of INTELSAT. In doing this, you would lose some of the high quality definition of the DOMSAT transmissions. On a dedicated receiver basis (i.e. one utilized primarily for INTELSAT) such a receiver can be adjusted for this prupose and left alone. Perhaps a second receiver would be set up for the 'wider' IF DOMSAT services. Another approach is to customize your receiver with an IF switching system; build into the receiver a pair of separate IF bandpass filters, one for 17.5 MHz bandwidth and one for 26 to 30 MHz bandwidth. Then with switches select the ap propriate bandwidth filter for the service you are receiving. An example of such a customized receiver is shown here. Perhaps eventually commercial receivers will adopt the same procedure; for now, if you are not technically able to do this on your own, you have to elect **which** of the two formats will be used most.



If you elect the 17.5 MHz format, your will be optimized for INTELSAT's common ''1/2 transponder'' format. You will not 'lose' DOMSAT reception; in fact you may even gain something in the way of DOMSAT system 'sensitivity' (a narrower IF bandwidth does that for you). **What you will lose** is some of the 'definition' (i.e. picture detail) on DOMSAT reception and in some instances the audio may also suffer on DOMSAT reception. If you are building a receiver on your own, you will be able to handle this simply because it is assumed you understand what you are doing anyhow. If you are purchasing a receiver, talk it over with your receiver supplier.

If you elect the full 26-30 MHz format, your INTELSAT reception will will be noiser than it could be with an optimized IF bandwidth; perhaps as much as 2.5 to 3 dB more noise. However - if your receiver employs a PLL (Phase lock loop) demodulator system you will find that the PLL system has a form of 'bandwidth limiting' built into it anyhow. The bottom line? The best compromise is a PLL receiver since it works well at below threshold signals and does some of its own adjusting.

C) **Recovering Audio** - The INTELSAT feeds are starting to standardize on a subcarrier in-channel audio feed located around 6.61 MHz; that is, removed from the video carrier frequency by 6.61 MHz (plus/minus .3 MHz). To properly recover the audio you will need to have a method of 'tuning' for the audio sub-carrier. Virtually all sub-detectors in all commonly employed receivers can be



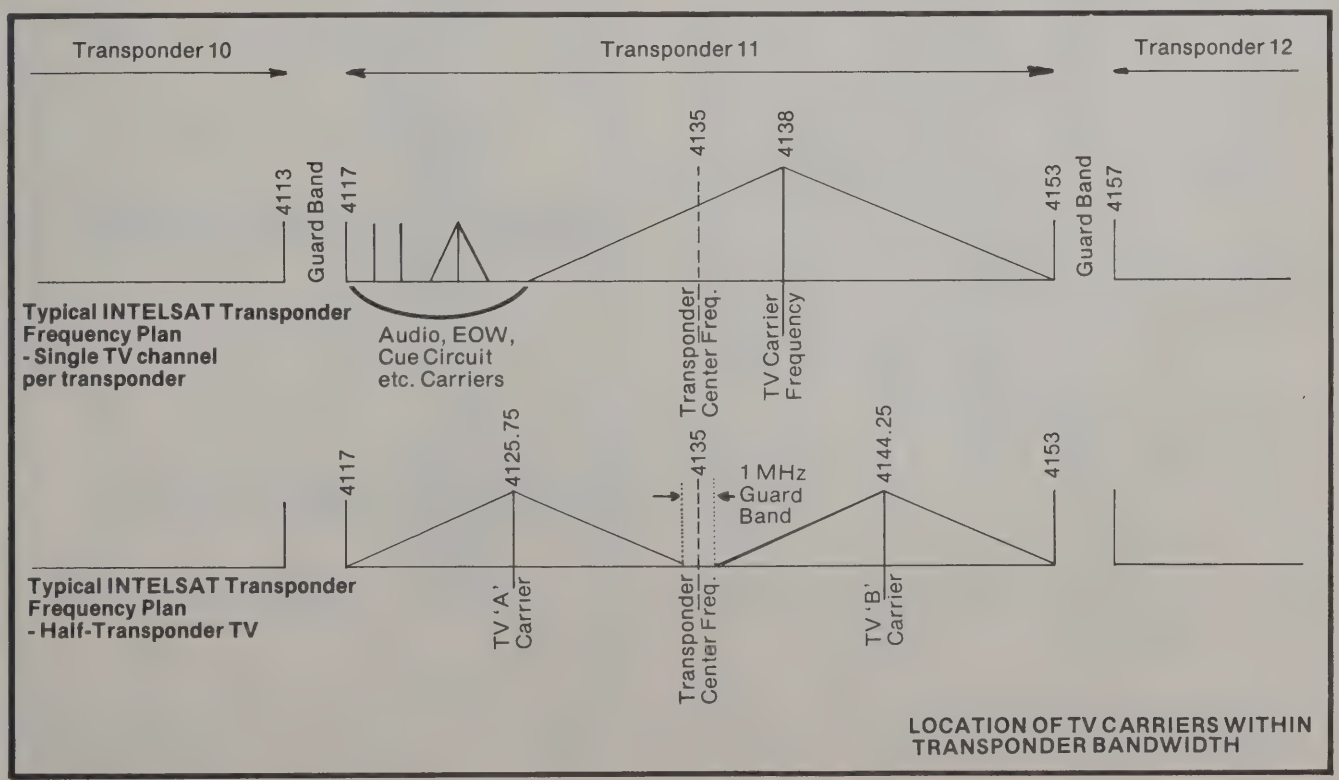
CUSTOMIZED 'Howard Terminal Receiver' built by California's Lance Ginner has switch selectable audio sub-carrier detection for all formats plus switch selectable video IF bandwidths.

'tuned' if you know which 'adjustment' to turn, and in which direction. If you are building your own terminal, you already know about this. If you are buying a terminal, you should ask the supplier how to do this with his receiver.

D)**The Tuneable receiver** - Not all of the INTELSAT/GHORIZONT/MOLNIYA frequency assignments (transponder channels) are the same as our DOMSAT assignments. This means that if you have a fixed-tuned receiver (one that 'steps' through the channels with dial-up numbers or push buttons) you may find that some of these international satellites are 'between' regular DOMSAT assignments; that you cannot tune them in. The answer is to select a receiver design that 'continuously tunes' the whole spectrum (3.7 to 4.2 GHz). In that way you can dial-in anything in the sky. This is particularly important with the INTELSAT 1/2 transponder as this places their 'center frequency' 1/4 channel up or down from a normal DOMSAT frequency (or more). As we shall see, with the Russian series satellites, it is even more important that you have continuous tuning.

E)**Video Format** - There are three major video formats in world; our North American NTSC system, a European system, called PAL and a French - Russian system called SECAM. When you plug your TVRO receiver into either an RF re-modulator or into a regular (NTSC format) video monitor, and receive a PAL or SECAM video signal, you have a 'standards conversion' interface problem. NTSC for example utilizes 525 lines of video while PAL and SECAM utilize 625 lines. NTSC has 30 complete picture 'frames' per second, PAL and SECAM have 25.

What this means is that when you tune in non-NTSC video on a NTSC video monitor or television set, you can expect the picture to not look exactly 'true'. How much out of kilter? Well, surprisingly little. Let's take what happens with PAL and SECAM, briefly. The primary impact of the 625 lines versus our NTSC line picture, and the 25 frames versus 30 frames, is an elongation of the vertical perspective of the picture. In theory, if your NTSC receiver is properly adjusted for vertical linearity and height, when you switch to a PAL/SECAM picture, it will be about 17% 'taller' than a NTSC picture. People become 'tall and skinny' and if the camera is 'tight' against the top of their heads, they may be headless (i.e, their heads disappear off the top of the screen).How do you correct this (assuming you don't care for tall, skinny people)? Simply readjust the vertical linearity and the height, one against the



other. That's it!

NOW - recovering PAL or SECAM in color (versus black and white) is a bit more of a problem. In fact it is quite an engineering trick. The best solution, if you are going to watch very much PAL/SECAM color is to locate (through your friendly Sony dealer) a video monitor which has been designed to word on either PAL color or SECAM color or with a switch perhaps on all three systems (Including NTSC). **But beware!** It turns out there are some variations to the basic PAL/SECAM schemes and at least one Sony monitor with it is sold as a 'tri-standards' (i.e. all three) is not suited for this application. (The Sony model PVM 1850 PS is listed as a tri-standards monitor; in truth it is for NTSC 'modified' or 4.43 MHz color plus PAL plus SECAM 'west'. It turns out that this particular monitor will display NTSC as it comes off the satellite in black and white since NTSC true color it NTSC 3.58 - not 4.43 - and worse yet it will desplay only the SECAM color system utilized in France and parts of the middle east; Russian SECAM color will not 'play' with this monitor.)

One approach to this problem was worked out by English experimenter Steve Birkill who described in the April and May (1980) issue of **Coop's Satellite Digest** a system to receive and convert the Russian (MOLNIYA and GHORIZONT) color to a NTSC compatible receiver/monitor. This schematic (for the advanced experimenter) is repeated in this manual.

Confused? You should be. Let's try to set it all straight:

F) **On your standard in-home receiver** you can tune in Russian MOLNIYA of GHORIZONT video, or INTELSAT PAL video in **black and white.** If you leave the receiver totally alone, the most you will suffer is having tall, skinny people. If you want it 'pure', readjust the vertical height and linearity controls for normal looking people.

G) **To get color,** you need a PAL (from Sony) monitor for INTELSAT. For Russian MOLNIYA or GHORIZONT you need to build up the Birkill standards conversion system detailed in CSD for April-May 1980 and for which a schematic is reproduced here.

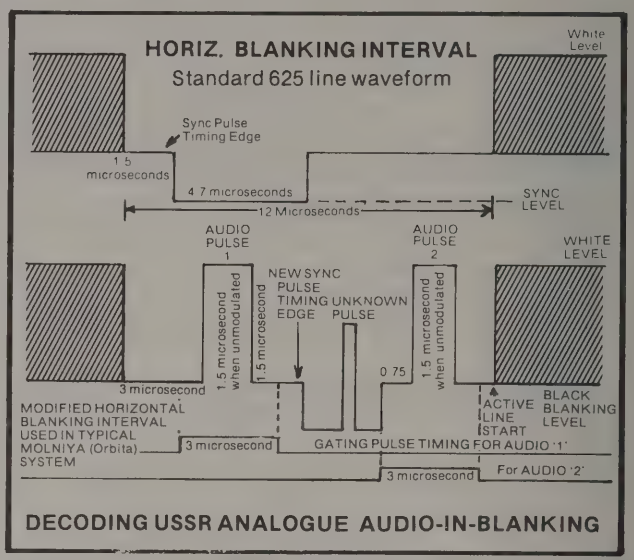
H) To get audio via INTELSAT you simply need a sub-carrier detector that tunes through the 6.61 MHz region (see separate part of this manual for a discussion of sub-carrier reception techniques and equipment). To get audio from Russian satellites, first you have to determine **which** Russian satellite system you are after.

The Russian GHORIZONT satellites (of which they presently operate GHORIZONT 2 parked at 14.5 degrees west longitude within reach of the eastern half of the USA) is just like INTELSAT; except the audio sub-carrier will be found at 7.5MHz, not the 6.61 MHz of INTELSAT. Simply use the sub-carrier detector in the normal way and tune it to 7.5 MHz.

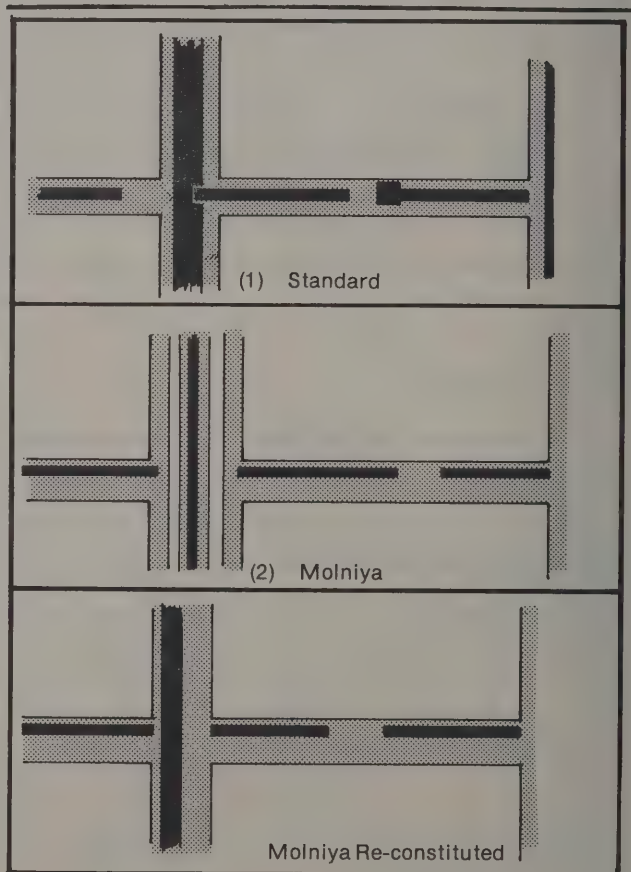
The Russian MOLNIYA series satellites (see separate section of this Manual) presents a more unique problem. The Russians have a unique 'sound-in-sync' or pulse width modulation (abbreviated PWM) in use with MOLNIYA. That is, the sound channel is transmitted during the horizontal blanking interval of the TV waveform. It turns out that the Russian MOLNIYA utilizes a **pair** of PWM 'channels', both inserted within this horizontal blanking interval. And they have been observed to carry 'program audio' (i.e. the audio that corresponds to the program being transmitted) on **either** of the two and sometimes on both (with two separate languages or dialects for different parts of Russia).

This might be a good point to note the very obvious. Russian television speaks Russian. At least on MOLNIYA (observers report that on GHORIZONT, which is the easy-to-copy 7.5 MHz standard sub-carrier format, that on occasion there may be Spanish or Finnish or German or whatever on the audio channel, when 'feeds' are going to countries where the language is not Russian). So do you **really** want to get involved in a construction project to copy Russian? Do you spead Russian? Can you stand to simply 'watch' a TV picture that does not 'speak' to you? Think about it.

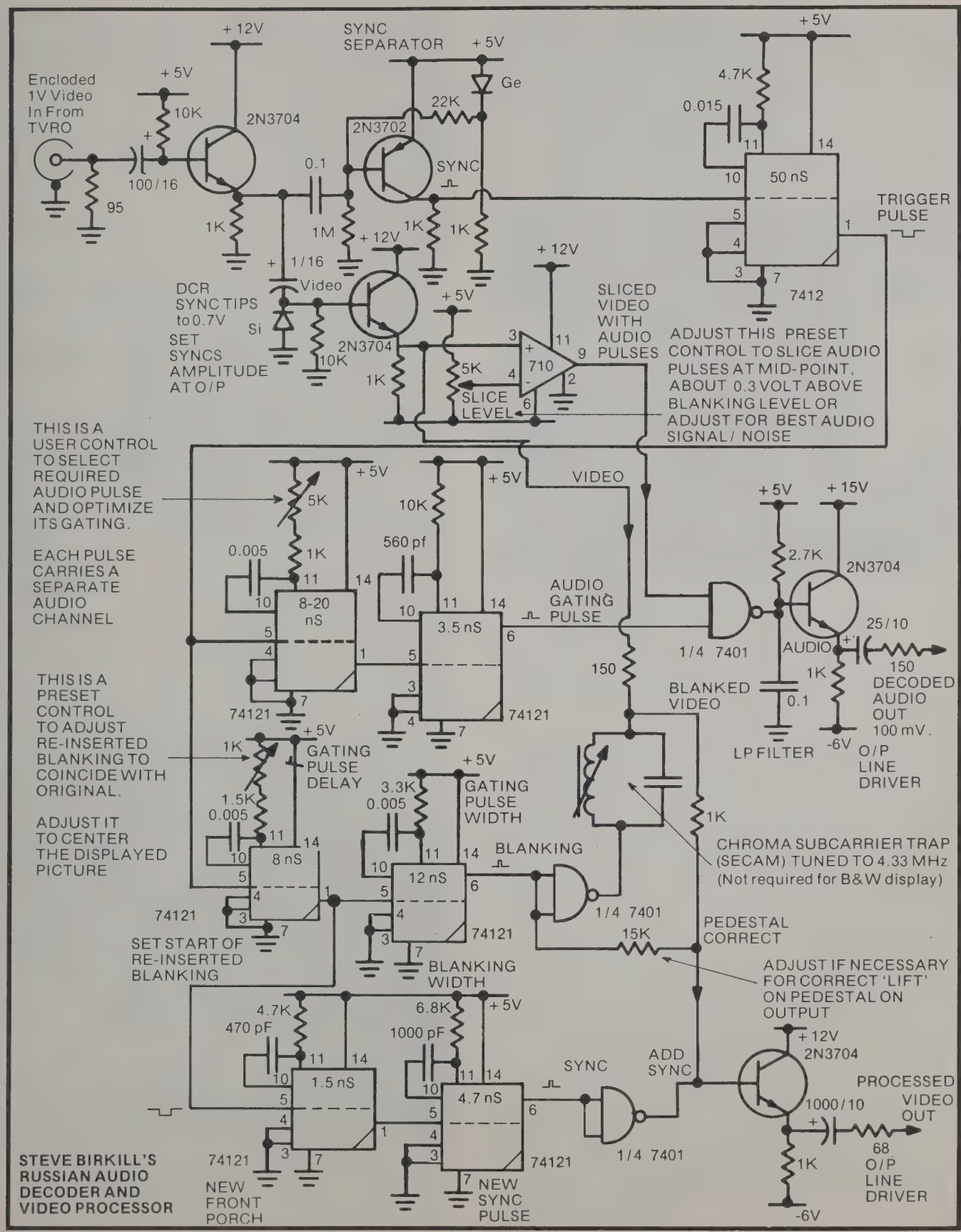
Back to the PWM system for MOLNIYA. By cramming a pair of PWM pulses with audio into the normal Horizontal Blanking Interval the Russian's 'clip' (i.e. shorten in length) the line sync pulse. That apparently does not bother their TV receivers although those of us who have tuned in Molniya will tell you that it produces a mild case of the 'jitters' on an NTSC receiver. To recover the audio with a system worked out by Birkill, and to recover color, and to stabilize the jitters, we refer you back to the Birkill standards conversion schematic diagram here in this section.



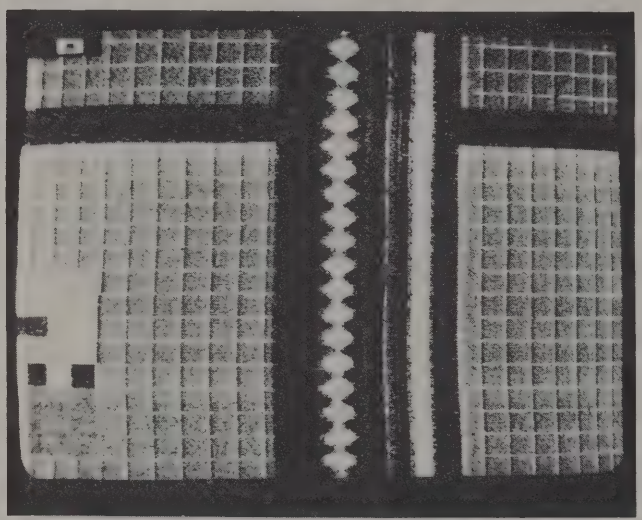
DECODING USSR ANALOGUE AUDIO-IN-BLANKING



The audio pulses are 'gated' out of the audio waveform. You 'slice' the pulse with the system shown in schematic form at about mid-pulse height and then gate it out with a locally generated gating pulse which coincides in time with the audio pulse (i.e. the gating pulse 'windows' the audio pulse and


Encloded 1V Video In From TVRO
+ 12V
+ 5V
10K
2N3704
100/16
95
1K
0.1
1M
SYNC SEPARATOR
+ 5V
Ge
22K
2N3702
SYNC
1K
1K
+ 12V
1/16
Video
DCR SYNC TIPS to 0.7V
Si
SET SYNCS AMPLITUDE AT O/P
2N3704
10K
1K
+ 5V
+ 12V
3
11
9
710
4
2
5K
SLICE LEVEL
6
SLICED VIDEO WITH AUDIO PULSES
ADJUST THIS PRESET CONTROL TO SLICE AUDIO PULSES AT MID-POINT, ABOUT 0.3 VOLT ABOVE BLANKING LEVEL OR ADJUST FOR BEST AUDIO SIGNAL/ NOISE
+ 5V
4.7K
0.015
11
14
10
50 nS
5
4
3
7
1
TRIGGER PULSE
7412
THIS IS A USER CONTROL TO SELECT REQUIRED AUDIO PULSE AND OPTIMIZE ITS GATING.
EACH PULSE CARRIES A SEPARATE AUDIO CHANNEL
5K
+ 5V
0.005
1K
11
10
14
8-20 nS
5
4
1
7
74121
10K
+ 5V
560 pf
11
10
14
3.5 nS
6
5
3
4
7
74121
VIDEO
AUDIO GATING PULSE
+ 5V
+ 15V
2.7K
2N3704
1/4 7401
AUDIO
25/10
150
1K
0.1
-6V
LP FILTER
DECODED AUDIO OUT 100 mV.
O/P LINE DRIVER
150
BLANKED VIDEO
THIS IS A PRESET CONTROL TO ADJUST RE-INSERTED BLANKING TO COINCIDE WITH ORIGINAL.
ADJUST IT TO CENTER THE DISPLAYED PICTURE
1K
+ 5V
GATING PULSE DELAY
1.5K
0.005
11
10
14
8 nS
5
4
1
3
7
74121
SET START OF RE-INSERTED BLANKING
+ 5V
3.3K
0.005
GATING PULSE WIDTH
11
10
14
12 nS
6
5
4
3
7
74121
BLANKING
BLANKING WIDTH
1/4 7401
1K
CHROMA SUBCARRIER TRAP (SECAM) TUNED TO 4.33 MHz (Not required for B&W display)
PEDESTAL CORRECT
15K
ADJUST IF NECESSARY FOR CORRECT 'LIFT' ON PEDESTAL ON OUTPUT
4.7K
470 pF
11
10
14
1.5 nS
5
4
1
3
7
74121
NEW FRONT PORCH
6.8K
1000 pF
+ 5V
11
10
14
4.7 nS
6
5
4
3
7
74121
NEW SYNC PULSE
SYNC
1/4 7401
ADD SYNC
+ 12V
2N3704
1000/10
1K
-6V
PROCESSED VIDEO OUT
68
O/P LINE DRIVER
STEVE BIRKILL'S RUSSIAN AUDIO DECODER AND VIDEO PROCESSOR

'grabs' it and hauls it off for separate processing). The Russian 625 line horizontal frequency is 15.625 kHz (easy to remember because of the 625 line standard!). This results in a line period (time span) of 64 microseconds. From the leading edge of the sync to center of the **second** pulse is **3.5 microseconds** and to the center of **pulse number 1** is **61.75 microseconds.** The peak pulse width with 100% modulation will be 3 microseconds. To insure high quality audio without distortion the pulse width should be 3.5 microseconds long. The gating pulses for audio pulses 1 and 2 should be created by a pair of monostables of 1.75 and 60 microseconds period and they in turn trigger a pair of monostables with 3.5 microsecond periods.



MOLNIYA signal with horizontal centering moved left to display PWM audio bars normally off-screen to right.

The resulting gating pulses are AND-ed (or NAND-ed with the sliced audio pulses (the gate outputs being just the varying width pulses) recurring at 15.625 kHz but varying in width at an audio rate. This is then sent through a low pass filter to remove the line frequency component (15.625) and the end result is 1 volt of audio (peak to peak).

This exclusive-to-MOLNIYA system may also be a difficult problem with any of the high-class (commercial) receivers which typically 'clamp' on a portion of the waveform called the back porch. It is within this region that the Russians have their abbreviated sync pulse plus their pair of PWM audio channels. One (the second) of the PWM pulses can 'fool' the typical back porch clamp and cause a severe case of the jitters. It turns out that private terminal receivers such as the SAT-TEC and Howard design clamp on sync tips and they will not be 'fooled' by the presence of the PWM signal in this region.

Egads this gets complicated!

The net result of messing around with MOLNIYA is probably that you will want to try to access this unusual bird (see special segment of this manual) but you probably will settle (as we did) for a slightly jittering black and white picture and no audio. Again, the GHORIZONT geostationary/Clarke orbit birds have few of these problems since they are configured differently. For an extensive discussion of what is really involved with MOLNIYA '**perfect reception**' dig up the appropriate April and May (1980) issues of **CSD.**

MOLNIYA LOCATING SYSTEM

To say that Molniya is in the Northeastern sky 'and moving' is a good way to dedicate several weeks to sky probing. You might get lucky and find it, but chances are your antenna azimuth and elevation controls will 'freeze' from repeated crankings long before you have success!

As you are now aware, the orbit takes the satellites from the south to the north, and they go into their apogee loop (or turn around and start to head back south again) at some 'window area' over northern Ontario in Canada. This point we shall call the sub-satellite apogee **zone** since it is not a true spot on the globe but rather an area several hundred miles east/west and north/south over which they perform their loop.

The best assistance to be given to you is to identify the general area over northern Ontario where the sub-satellite apogee zone falls. This will be a spot you can find on your own globe or North American Atlas and then following the steps given here you will determine your own elevation and azimuth headings for your specific location.

The location to look for on your globe/map is Mansel Island in the northern Hudson Bay of northern Ontario, Canada. It is approximately over this island where the apogee loop takes place although the 'zone' extends further than just the island itself.

The following steps, taken by you, plus the guide of the charts and tables here, should put you close enough to Molniya apogee loops with your own antenna system that you will find a transmission within an hour or two of your initial searching. We'll talk about what you do after finding the first one shortly.

1) **Remember** that Molniya is moving in two planes; it is moving left and right (your azimuth adjustment) and it is moving up and down reference your spot on earth (your elevation adjustment).

2) **The best suggestion** is to align your antenna so that it points directly towards Mansel Island; just as if you could see it some 25,000 miles above itself.

With our ADM 11 foot antenna we calculated our true

74 DEGREES and rising! MOLNIYA exists North America with transmitter running turning off as much as 74.5° elevation above Oklahoma.

heading to Mansel Island from a North American Atlas (it turned out to be around 22 degrees true; and that means after allowance for our magnetic declination in Oklahoma) and then we shifted the ADM antenna around on a concrete pad so that its 'polar axis line' (the line created by its base support steel support system and bi-sected by the elevation adjustment turnbuckle at perpendicular angle) fell on our Mansel Island heading. In effect, we **pretended** that a line from Oklahoma to Mansel Island was a polar-axis alignment north-south line.

This meant that for a bird in apogee, the antenna would tip directly back (or move directly ahead) in-line-with the mount support.

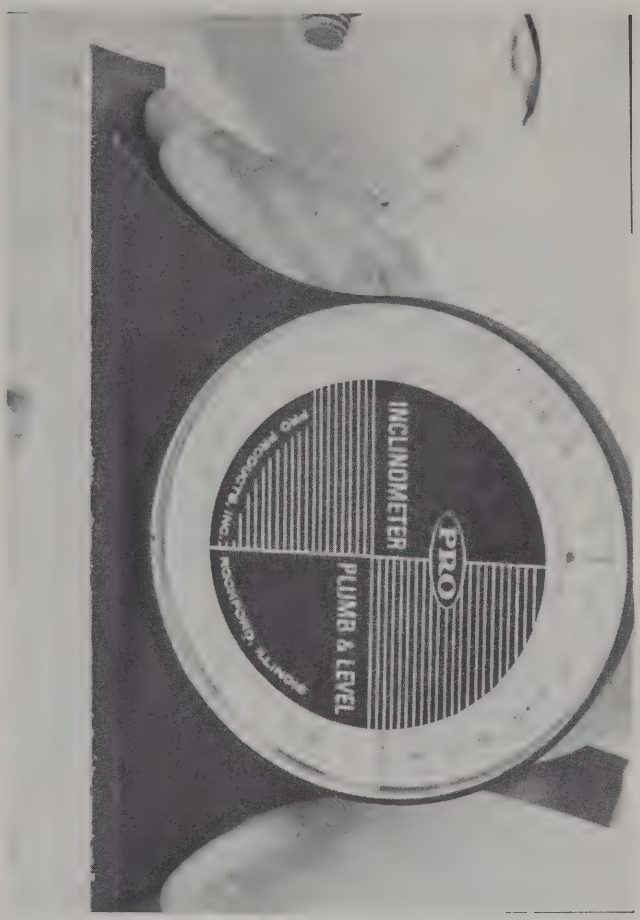
FINDING ELEVATION is simply a matter of locating piece on antenna that reflects actual elevation [tilt] of dish. This indicates 74°.

3)**NOW** - since the azimuth variation during the bird's (average of six hour) 'active period' is far less than the antenna's elevation adjustment (this may 'add-up-to' as much as 19 or 20 degrees of 'tracking' from bird turn-on down through apogee and back out to turn-off), with the antenna aligned on the approximate center of the average of all apogee headings you can 'relax' and let the elevation control adjustment do 90% of the tracking exercise.

What you actually do is decide where the bird is when you first catch it. If it is coming towards apogee (and this can be confusing since as it goes **towards apogee** it gets **lower and lower in your sky**, moving to the north) you will track it within a degree or so from turn on (in azimuth adjustment) to the apogee point. At apogee it will loop and turn towards your east (i.e. shift across your sky from west to east) by between 2 degrees and 4 degrees before it **then starts moving back out of apogee** and (and again this can be confusing!) towards you. Remember it goes from south to north, turns east in your northern sky, and then travels back south again.

The biggest change in azimuth is that 60-90 minutes as it shifts from the south-to-north to the north-to-south mode. Once it finds its final 'now-leaving-apogee' heading you can again rest and concentrate on the elevation adjustment. As it moves away from apogee, or north to south, it will climb higher and higher in your sky. Here in Oklahoma it reaches elevations as great as 74 to 74.5 degrees before the Russian ground controllers shut it off and switch service to the next bird in the line. That means for someone 16 degrees further north than Oklahoma (i.e. along the US-Canadian border) Molniya is dead overhead or straight up when they shut it down(!). That ought to make a shiver run down your back.

You will note in the charts and tables here that the Molniya birds are not at the present time being turned on until they are quite close to the apogee loop turn-around; that is, they are typically with 3 to 4 degrees of their lowest elevation for you when they are switched on. This may be a **temporary** situation since the birds obviously could be activated at about the same point heading north as they are turned off heading



FINDING AZIMUTH - first align your dish on a known heading; then calculate against that heading using properly positioned piece of antenna hardware as reference.

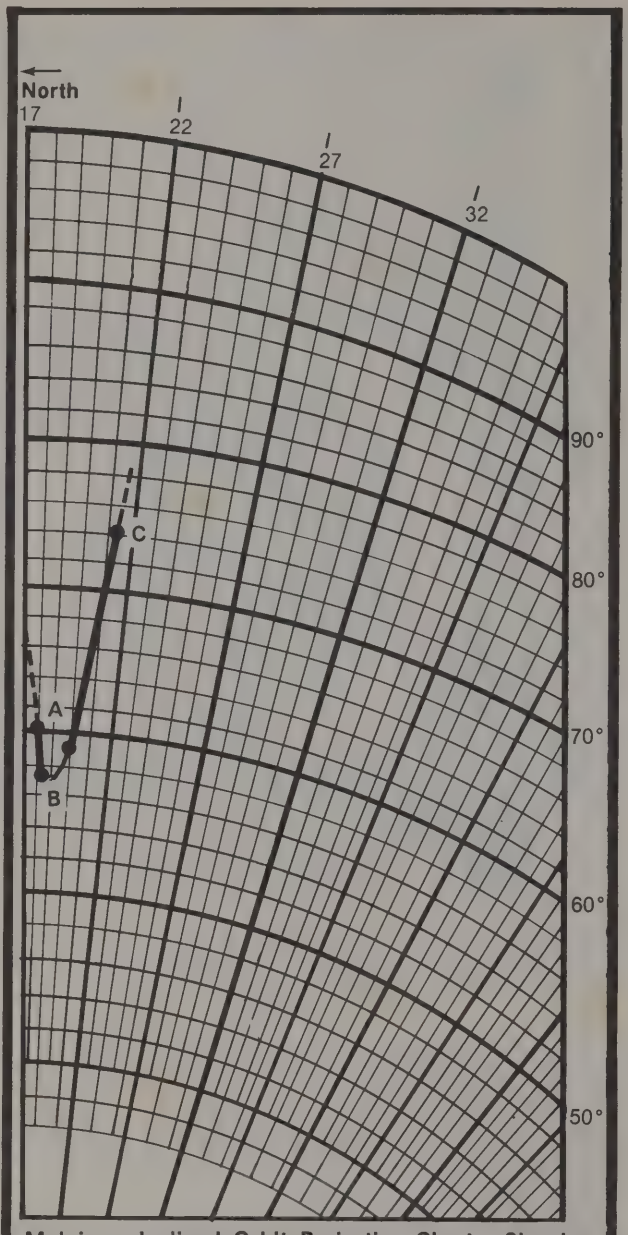
south.

4)**With the charts here** are a pair of 'blank charts' which you can copy out of this Manual to make your own observation flight charts.

Diagram M-1 depicts the observed pattern for the Molniya bird that turns on at 8:36 AM CDST. Actually that is far too precise because that turn-on time was good only on one day; June 18, 1980! What is that all about?

Well, there is an observed 'regression rate' wherein it appears, based upon some 30 days of observations from mid-May 1980 through mid-June 1980, that the birds are losing about 4 minutes and perhaps 20 to 30 seconds each day. That is, they do **not** make the 'round trip' about the earth in precisely 24 hours (00 minutes 00 seconds) but rather they seemed (in the observation period noted) to be making the trip in 23 hours 55 minutes and between 30 and 40 seconds. This says they get to the same sub-satellite point (on earth) in less than a full 24 hour time span. The Russian controllers satisfy or correct this problem **by moving the time** they turn each bird on and off approximately 4 minute back per day. If the bird turns on at 8:36 AM CDST on June 18th, it will turn on at around 8:32 AM on June 19th. **It will be at the same point in the sky** (and above the same sub-satellite point) **on both days however**.

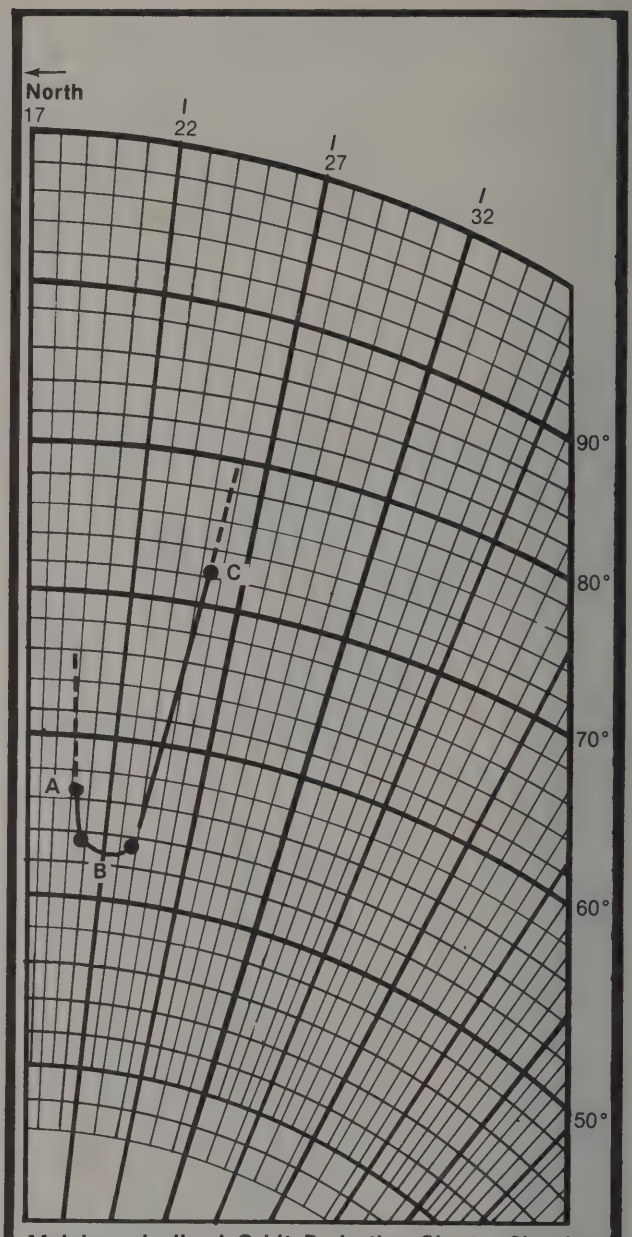
Therefore you not only have to track the bird across the sky in elevation and azimuth but you must also make allowances when you go looking for it for the fact that for each day between observations and a reference point in time (i.e. you find in turning on at 8:36 AM at 60 degrees elevation and 18 degrees true azimuth on June 18th, you will find it at the same elevation/azimuth heading nearly 30 minutes **earlier** on June 25th; one week later).



Molniya - Inclined Orbit Projection Chart - Showing apogee route, azimuth is horizontal [17, 22, 27, 32]; elevation is vertical [reference overhead equals 90°]. [Plots for Oklahoma]

MID—JUNE 1980 Molniya apogee/turn on — off for early morning 'US' bird.
A = Turn on at 68° elevation, 18° true 1336 GMT.
B = Apogee at 57° elevation, 20.75° true at 1522 Gmt.
C = Turn off at 74° elevation, 21.5° true at 1854 GMT.

DIAGRAM M—1

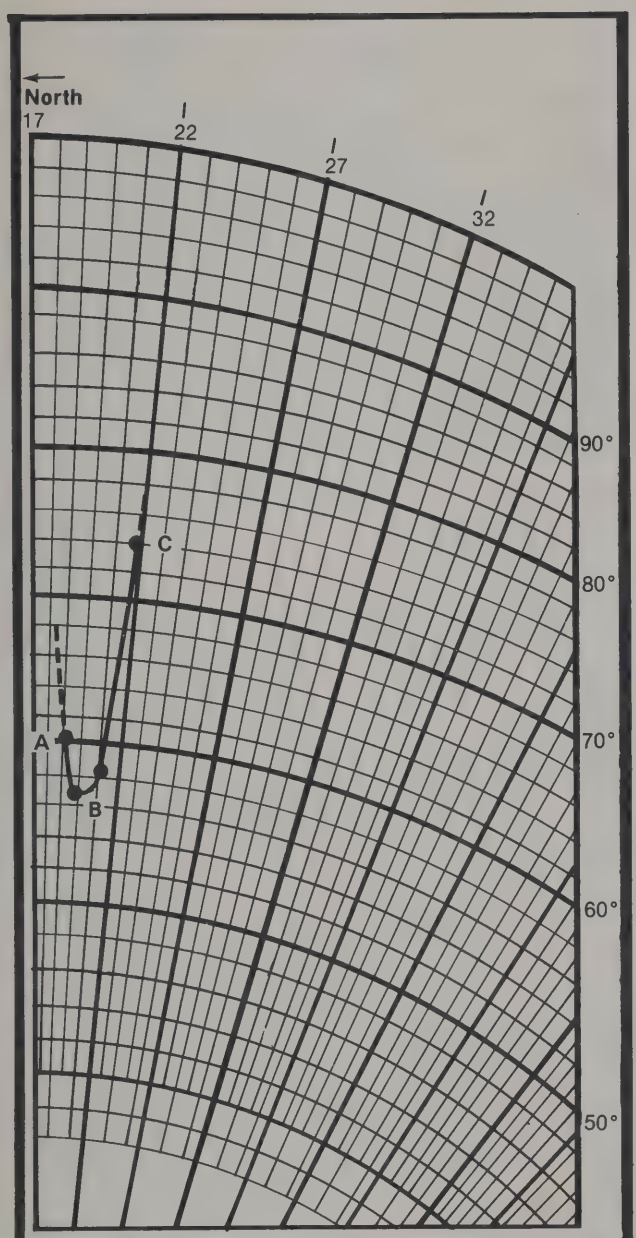


Molniya - Inclined Orbit Projection Chart - Showing apogee route, azimuth is horizontal [17, 22, 27, 32]; elevation is vertical [reference overhead equals 90°]. [Plots for Oklahoma]

MID—JUNE 1980 Molniya apogee/turn on — off for afternoon 'US' bird.
A = Turn on at 57° elevation, 20.5° true at 1854 GMT.
B = Apogee at 53° elevation 20.75° true at 2100 GMT.
C = Turn off at 72.5° elevation 25.5° true at 0112 GMT.

DIAGRAM M—2

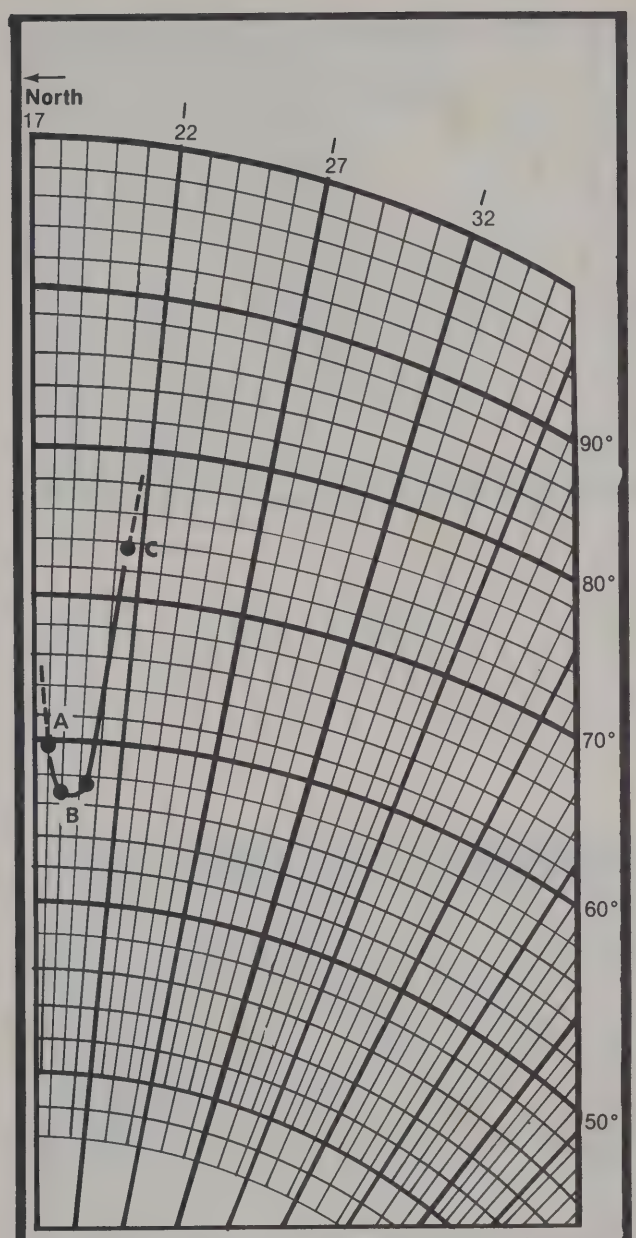
This presents no problems to the Russian controllers; they switch from one bird at turn off to one bird at turn on far faster than I have ever been able to manually crank the 11 foot ADM antenna from turn off point to turn on point in the sky. It **is fun** to anticipate the switch, **to leave** the turn off bird sixty seconds or so before it will turn off and be ready for the turn-on bird when it comes on. As those who have seen the **'They Call this Bird Molniya'** STT videotape **[1]** can see when the bird first comes on there is a characteristic 'overshoot' look to the picture. The video 'whomps' up strong, drops back to a lower level and then 'flutters' for a few seconds until it stabilizes. This could be the uplink antenna homing in on the bird or simply the AGC system in the bird's receiver (transmitter) package responding to the sudden presence of signal. It does



Molniya - Inclined Orbit Projection Chart - Showing apogee route, azimuth is horizontal [17, 22, 27, 32]; elevation is vertical [reference overhead equals 90°]. [Plots for Oklahoma]

MID—JUNE 1980 Molniya apogee/turn on — off for late evening 'US' bird.
A = Turn on at 60° elevation, 19.5° true at 0112 GMT.
B = Projected [not verified] apogee at 20° true, 57° elevation at 0315 GMT.
C = Projected [not verified] turn off at 22° true 74° elevation at [approximately] 0700 GMT.

DIAGRAM M—3



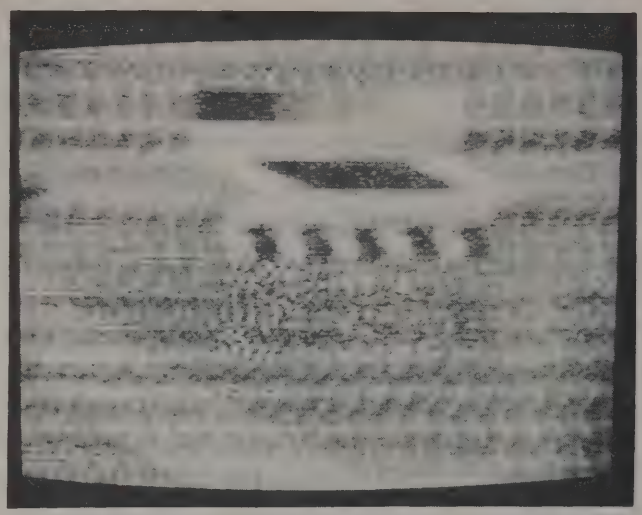
Molniya - Inclined Orbit Projection Chart - Showing apogee route, azimuth is horizontal [17, 22, 27, 32]; elevation is vertical [reference overhead equals 90°]. [Plots for Oklahoma]

MID—JUNE 1980 Molniya apogee/turn on — off for wee—hours 'US' bird. A = Projected [not verified] turn on at 0700 GMT [approximate at 60° elevation, 18° true. C = Turn off [verified] at 74° elevation, 21.5° true at 1336 GMT.

DIAGRAM M 4

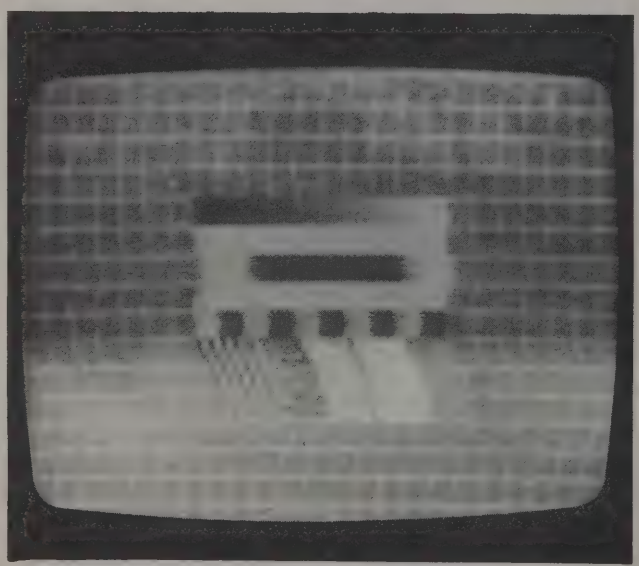
appear the Russians **actually move** (!) the uplink antenna from one bird (at turn off) to the next bird (at turn on) in spite of logic that suggests they would have two separate uplink antenna systems going and would actually turn on the new bird a few seconds or minutes before they turn off the old bird. It is a bit intriguing to know that as **they** switch birds several hundred Molniya ground stations (and their operators) scattered throughout Russia are doing the very same thing you are doing at the very same time!

Now that Molniya watching is becoming quite popular, regular **CSD** (Coop's Satellite Digest) updates will attempt to keep you advised of the 'regression rates' observed so that you won't find yourself picking up this Manual months after the given 'calibration points' wondering where it might be at this

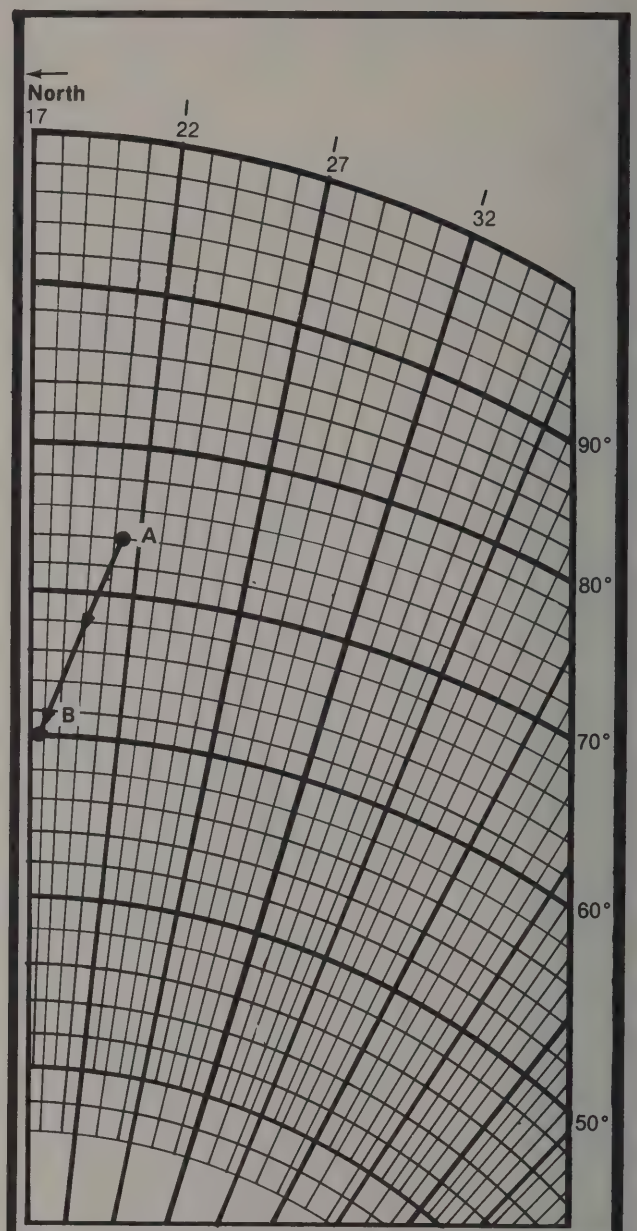


MOLNIYA with 180 Kelvin LNA and linear feed on ADM 11 foot antenna. You 'could' watch it!

point in time. However, as long as nothing is done to the forward speed of the birds we feel (based upon the 30 days observations) that it will be safe to assume that you have between 28 and 32 minutes of change from the diagram M1-M4 charts here **per week** for each week after the middle of June



MOLNIYA with 180 Kelvin LNA and [Birkill] right hand circular feed on 11 foot ADM. Now it is starting to look good!



Molniya - Inclined Orbit Projection Chart - Showing apogee route, azimuth is horizontal [17, 22, 27, 32]; elevation is vertical [reference overhead equals 90°]. [Plots for Oklahoma]

TURN OFF to turn on antenna movement required [example]. A is turn off of bird at 74° elevation, 21.5° true and B is turn on of follow—up bird at 60° elevation, 18° true. Your antenna must make this 'trip' at the point of change over.

DIAGRAM M—5

---

[1] 'They Call This Bird Molniya' is a 2 hour videotape production of STT that portrays the first US reception of Molniya on a low-cost private terminal. Included is detailed antenna aiming and tracking data, equipment descriptions and discussions, examples of Russian television programming and the historic moments captured on videotape of the first reception. It is available on BETA or VHS format for $60 from Satellite Television Technology, P. O. Box G, Arcadia, OK 73007.

1980. Here are some projected correction figures:

1) **July 15, 1980** - birds wil be appearing at the diagram/chart locations 118 minutes earlier than indicated.

2) **August 15, 1980** - birds will be appearing at the diagram/chart locations approximately 4 hours than indicated.

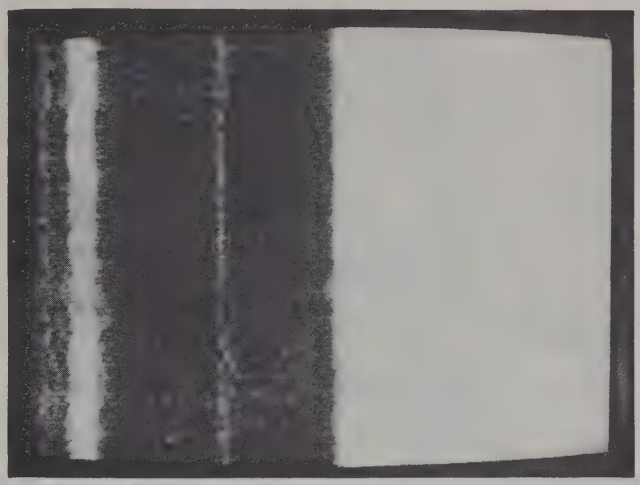
BASIC MOLNIYA set up. Black and white monitor, tuneable receiver [Sat-Tec], 7.5 MHz sub-carrier audio detector and amp, inclinometer!

Now this continual regression **may not go on forever** (although logic suggests it is fuel-expensive to correct) and that brings us to the normalized operation periods for Molniya. Molniya begins the broadcast 'day' for their most eastern coverage zone (Siberia) at 8 AM Siberian time which happens to be 12 midnight in Moscow. **You** may well be so located that you are 12 hours earlier than Moscow (i.e. 12 noon) and that suggests that if we are going to keep ourselves 'straight' we need to adopt a 'universal' time for reporting on Molniya. We have done so here, using the Greenwich Mean or Universal time system wherein everyone adjusts their local time to the time at that instant in London, England (on the Greenwich Meridian). This is not a complicated adjustment to make:

EDST - add **4** hours to your local time
EST/CDST - add **five** hours to your local time
CST/MDST - add **six** hours to your local time
MST/PDST - add **seven** hours to your local time
PST - add **eight** hours to your local time
YST - add **nine** hours to your local time
AST/HST - add **ten** hours to your local standard time

Examples? When it is midnight in Moscow (and 8 AM in Siberia) it is 5 PM 'yesterday' in the US eastern time zone. All of the charts/diagrams shown here are in GMT or Universal time. Thus the broadcast 'day' for Siberia begins at 2200 GMT.

NOT 4 GHz NOISE - The fine grain noise left in this picture is due to baseband noise. See video low-pass filter on page 52 here to cut down demodulator noise.



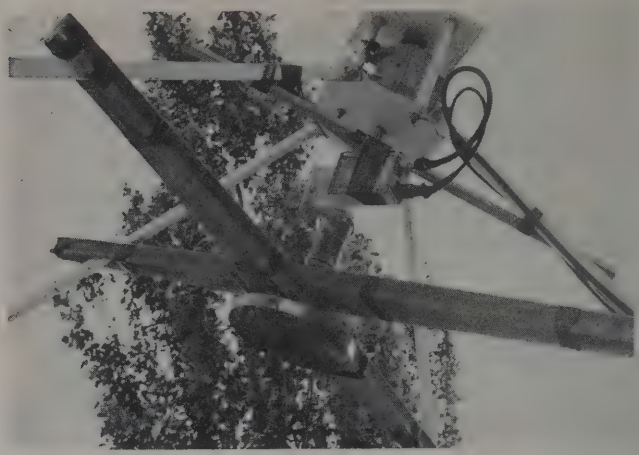
PULSE AND BAR pattern; used some but not as often as test card shown here by MOLNIYA. Pattern is easy to spot in the noise!

TALL, SKINNY RUSSIAN. Before you adjust vertical linearity control all Russian people will look like basketball players. Note time in Moscow - 0554 [AM]!

The first transmission is a program of **Novosti** or news. It typically lasts for one hour and is followed by a childrens feature. The kiddy show includes stick puppets and some animated cartoons. A film feature usually follows the kiddy show and this is often a 'propaganda piece' designed to show off some new construction feat or some aspect of the 'social revolution'. By 0100 GMT or so on weekdays they may discontinue programming and go back to their familiar test card. Keep in mind this is midday in Siberia.

Saturday and Sunday are the big TV days in Russia. Sporting events (they are seasonal like ours; soccer in the summer, hockey in the winter with quite frequent feeds from the Eurovision network) and 60 to 120 minute 'plays' filling much of the broadcast day after the kiddy show and news. News briefs are dropped in at the end of program segments and segments may just as easily last 68 minutes as an even 60.

HYBRID MODE [circular] feed is bulky and needs to be carefully supported at dish focal point. We used wooden slats to center ours!



LNA CONNECTS to N connector on feed through UG-57 B/U connector ['splice'] and is 'taped' to supports to keep strain off of feed waveguide proper.

Molniya will go to their test card to fill out a 30 minute period if the preceding program ran over a natural one hour or 30 minute break and then they will start the next program on a half or full hour time mark. There is no apparent effort to switch satellites at a natural break; they drop off in mid-sentence as often as not.

Based upon our experience you can expect the following results with your own installation:

1) **With a 180 degree LNA**, linear feed (horn), PLL receiver and an 11 foot dish you will get watchable pictures with a carrier to noise in the 5-6 dB region.
2) **With a 120 degree LNA**, circular feed, PLL receiver and an 11 foot dish - you will get virtually noise free pictures.
3) **With a 120 degree LNA**, circular feed, PLL receiver and a 13 foot dish you can read all of the detail shown and be sure you are inside Molniya itself.
4) **With a 120 degree LNA**, circular feed, PLL receiver and a 16 foot dish you will have a video signal to noise ratio in the 51-2 dB region and that's probably a couple of dB better than the Russians get with their 12 **meter** antennas and 500 degree Kelvin front ends!

As noted elsewhere you will need the Birkill designed Pulse Width Modulation decoder and standards conversion system to add Russian program audio (the audio that actually goes with the picture) and color to your system.

The 7.5 MHz audio sub-carrier found on Molniya is an easy to copy and interesting service. It might be compared to one of our national (NPR) public radio service channels. Music and news is distributed on this sub-carrier and while most of the music is Russian you will on occasion here Spanish (Cuban) French and yes...even (England) English tunes.

The 3875 MHz carrier center frequency is modulated into slightly greater deviation than our standard 36 (40) MHz wide carriers. We **expected** the phase lock loop demodulators to have some difficulty copying all of the video deviation. For black and white service the PLL seems to do just fine although the color may be more of a problem; we are simply not sure yet.

Displaying Molniya

In a normal satellite feed you either feed the baseband video from the receiver to a 'baseband monitor' or you feed it into an RF modulator. Here is what we have found to date:

1) **Even though** you will **not** copy the SECAM color energy on an NTSC color receiver or monitor, we have found that NTSC color monitors are apt to have horizontal streaking in the picture even when the color level control on the monitor is turned completely off.
2) **Interestingly**, when the same video signal is fed to a black and white monitor, there is none of this horizontal banding or lines. The banding, by the way, is in black and white even on the color monitor with the color turned up.
3) **Suspicious** that we were getting some high frequency video components into the monitor we built up a video low pass filter that allowed everything below 4.2 MHz to pass through (**see Video Low Pass filter schematic here**) but provided some attenuation above 4.2 MHz. This did **not** clear up the horizontal banding on the color monitor but it did improve the video signal to noise ratio on several (CONRAC brand) black and white monitors and a Setchell Carlson black and white monitor.

If you look closely on the black rectangular portion of the Molniya test card, either here or in your own reception, and you notice there are **no sparklies** or dancing noise dots in this part of the pictuare, you can be reasonably sure that your 4 GHz receive system is functioning so that your system is **out of** 4 GHz noise. **However**, the picture will probably still have a **grainy appearance**; not unlike that you get when you press your nose up against the CRT on a standard US receiver even with a 'perfect' picture. Simply stated, you still have noise but now it is in the demodulator section of the receiver and the circuits that follow. And if you have several different monitors around to try the signal on (at baseband - not RF) you will probably notice some have it and some do not.

We ran the demodulated video waveform out of the receiver into a number of standard modulators including the modulators found in VCR units. Guess what! It remodulates the NTSC modulator just fine, in glorious black and white. So you can treat the Molniya video just as you would your DOMSAT video and expect to get about the same results with remodulated Molniya through an NTSC remodulator as you would get by looking at it directly at video baseband with a baseband monitor.

There are two adjustments to be made to the receiver if you are a purist.

1) Make sure any receiver you use has an accessible vertical hold control.When you first tune in Molniya you'll have a picture that flips (up usually). Their frame and field rate differs from our NTSC signal and by adjusting the vertical hold control you'll make it lock up. (Newer receivers with no vertical hold control are bad news!).
2) **At that point** you will notice the Russian people are all tall and skinny. They aren't. You need to reach behind or inside of your receiver and readjust the vertical linearity control; again, their picture standards differ from ours (625 lines versus our 525 lines) and you have to 'pull' the top and bottom of **their** picture back onto your 'more narrow' picture tube. Or leave it alone and tell your friends all Russians look that way!
3) Because Molniya transmits its program audio as a pulse width modulated carrier, there is an extra set of signals (two) locked up in their horizontal blanking interval. These signals cause virtually any NTSC monitor or re-

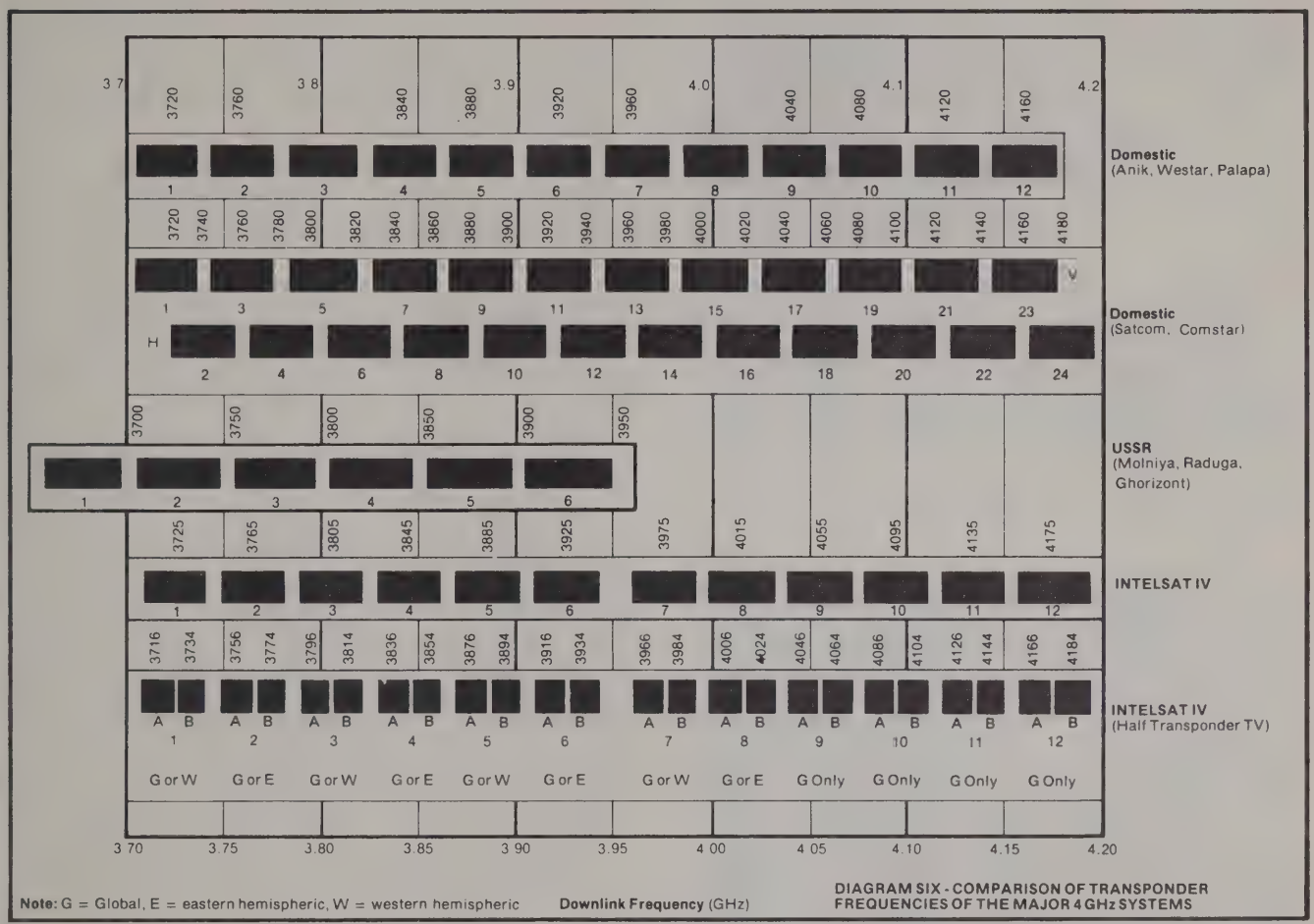


DIAGRAM SIX - COMPARISON OF TRANSPONDER FREQUENCIES OF THE MAJOR 4 GHz SYSTEMS

ceiver to have a very mild to quite severe case of the horizontal jitters. The ultimate cure is the Birkill designed audio demodulator and video processor. An easier semi-fix is to make sure your reciever/monitor has an accessible horizontal hold control. You'll want to twist it slightly to get the jitter to a bare minimum. Again, some newer US receivers don't even have such a control so be careful in selecting a receiver or monitor! If the receiver/monitor has a horizontal centering control or width control you can pull the edges of the screen in and on the right hand edge of the screen you will see a pair of vertical traces. These traces (one may be a thin white line while the second may either be a series of vertical trapezoids if they are transmitting a test pattern or a constantly changing pattern if they are into programming) are their PWM audio channel and by pulling the picture in from the sides you can see them in what would normally be our horizontal blanking interval.

Operating Strangeness

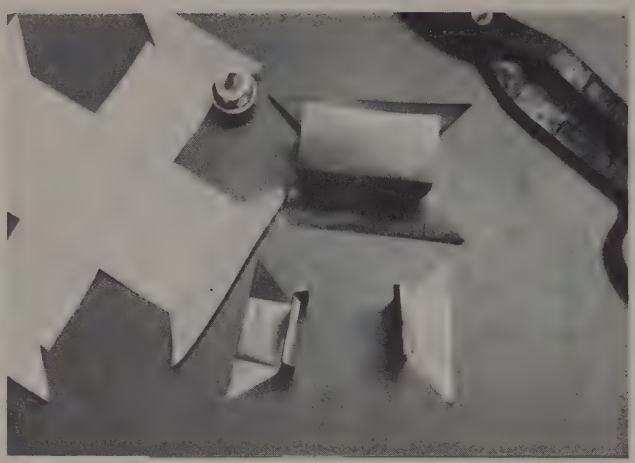
Because Molniya is on a 'Global' beam pattern, we can expect the signal level to vary from beam center (or boresight) of 34 dBw to approximately 31 dBw at beam edges. That places most of North America in the 32 or 33 dBw area (an EIRP you can recapture **if you match** their right hand circular polarization). The path length of Molniya between apogee (their furthest point from you at the lowest look angle) and the higher look angles as they start or stop transmission varies quite remarkably; you can actually measure more than **2 dB less space** loss in the signal as it nears the shut down point furthest south over North America. It is during these last 30 minutes or so just before they shut down that they are closest to you (in North America) and while the signal is perhaps 2 dB (or a tad more depending upon where you are) stronger at that point they are also moving most rapidly then too. In fact, between 30 and 60 minutes prior to shut down of a particular bird you will find you have to readjust your antenna every 8 to 15 minutes to keep the picture peaked up.

There are some periods of the day when they shut down the whole bird. They usually precede such an action with their test card for a few minutes. If you check between 1430 and 1900 GMT you may for as much as 60 minutes (at random times) find no sign of Molniya even though it is there humming along quietly. **They simply shut it off.**

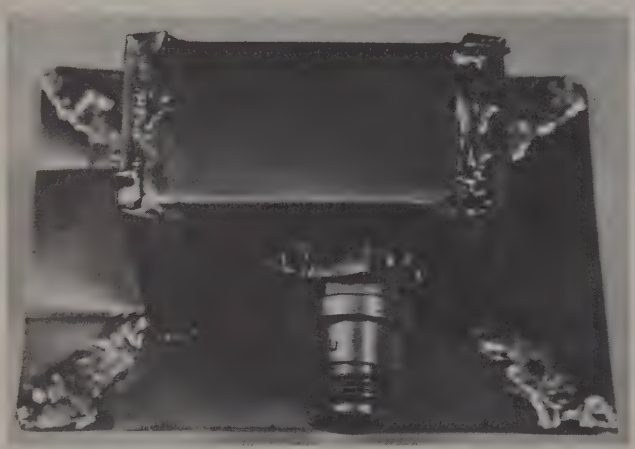
The most exciting time to tune in is in the 2030 to 2300 GMT period. Starting at 1530 (often 1430 on weekends) they do lots of uplink transmitter testing running any number of strange looking test patterns, square waves and what have you through the bird. Just prior to the commencement of their 'Good Morning Siberia' newscast, or around 2155 GMT, you will see a sort of official sign-on sequence which begins with their national anthem, a clock supered over the video showing you it is just minutes before midnight in Moscow, and an animated sequence that identifies the service as the T3 service of Orbita. They are very punctual about starting the news at 2100 GMT; you can set your watch by it and in fact they run a large clock with a second hand that steps in one second increments just ahead of the opening of the news. I've checked it against WWV and it is dead on!

WAVEGUIDE TO COAX ADAPTER

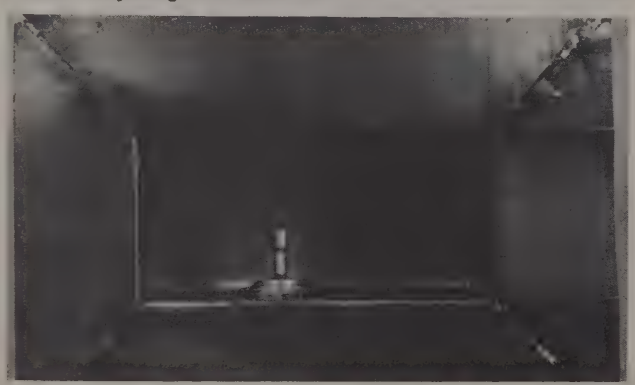
One of the biggest 'problems' if you are either homebrewing your own LNA or if you are building the Birkill Hybrid Mode feed system for selectable right hand circular, left hand circular or linear vertical or linear horizontal polarized signals...is to decide how to get the antenna



ESSENTIAL PARTS for Waveguide To Coax Adapter shown on page 51. Sheet brass or copper is material used.



SOLDERED UP ADAPTER - can be made to look-pretty but if inside edges are filed smooth performance will not be tarnished by rough outside look.



INSIDE of Waveguide To Coax Adapter you can spot the 9/16th probe soldered to the center pin on the chassis mounting type N connector.

delivered signal **out of** the feed horn and into either your homebrew LNA or into your commercial LNA.

The homebrew LNA is the easiest but also troublesome. Your feedhorn, regardless of design, either has or can be outfitted with a 'probe'; which is a piece of copper wire perhaps #12 or 14 that measures 9/16ths of an inch long protruding into the feed horn chamber. This probe is mounted on the tip end of a type N coaxial connector (chassing mounting type). With this probe mounted on your feed you now have a coaxial connector into which you can plug a (short) piece of coaxial line to run to your LNA.

However - any coaxial line between the probe on the horn and the input to the LNA is going to cost you some signal loss. And this signal loss is occurring **prior to** LNA (amplification) and that is very bad news indeed since even 1 dB of loss here can be the equivalent of reducing say an 11 foot antenna to a 10 foot antenna!

One solution is to bypass any coaxial cable at all; go from a type N horn connector through an Amphenol type UG 57 B/U which is a male to male transition or barrel type connector. This will allow you to go from the female connector on the feed to the female connector on the LNA without any actual coaxial line in between. The 57 B/U coupler will cost you between .1 and .2 dB however.

Now if you are using the Birkill Hybrid Mode feed **or** if your LNA does **not have** a type N input connector, what do you do? Most commercial LNAs have a **flange input**; an open mouth that mates with the corresponding flange on the feed.

You obviously cannot plug a coaxial fitting into a flange! What you mut do is to place a coaxial connector on the flange. It is not complicated.

Shown here is a set of photos and a drawing of a 'waveguide to coax' adapter. The particular one shown in the photos was created out of brass shim stock; the type of material you will find (if you look long enough) in auto parts houses. Sheet brass or sheet copper, stiff enough to 'hold its form' will do just fine. As you can see from the drawing and the photos we have built up a special box that is dimensioned like a piece of waveguide. One end of the box or waveguide is shut off with a wall; the opposite end is open, through a flange, and this home brewed flanged-end bolts onto the flange of the LNA. The wave-guide-to-coax adapter has a type N fitting positioned in it and a probe soldered onto the center pin of the connector.

You can connect the input connector of the waveguide-to-coax adapter to your feed antenna output either through a short length of coaxial cable (bad choice) or via the Amphenol UG 57 B/U fitting previously noted.

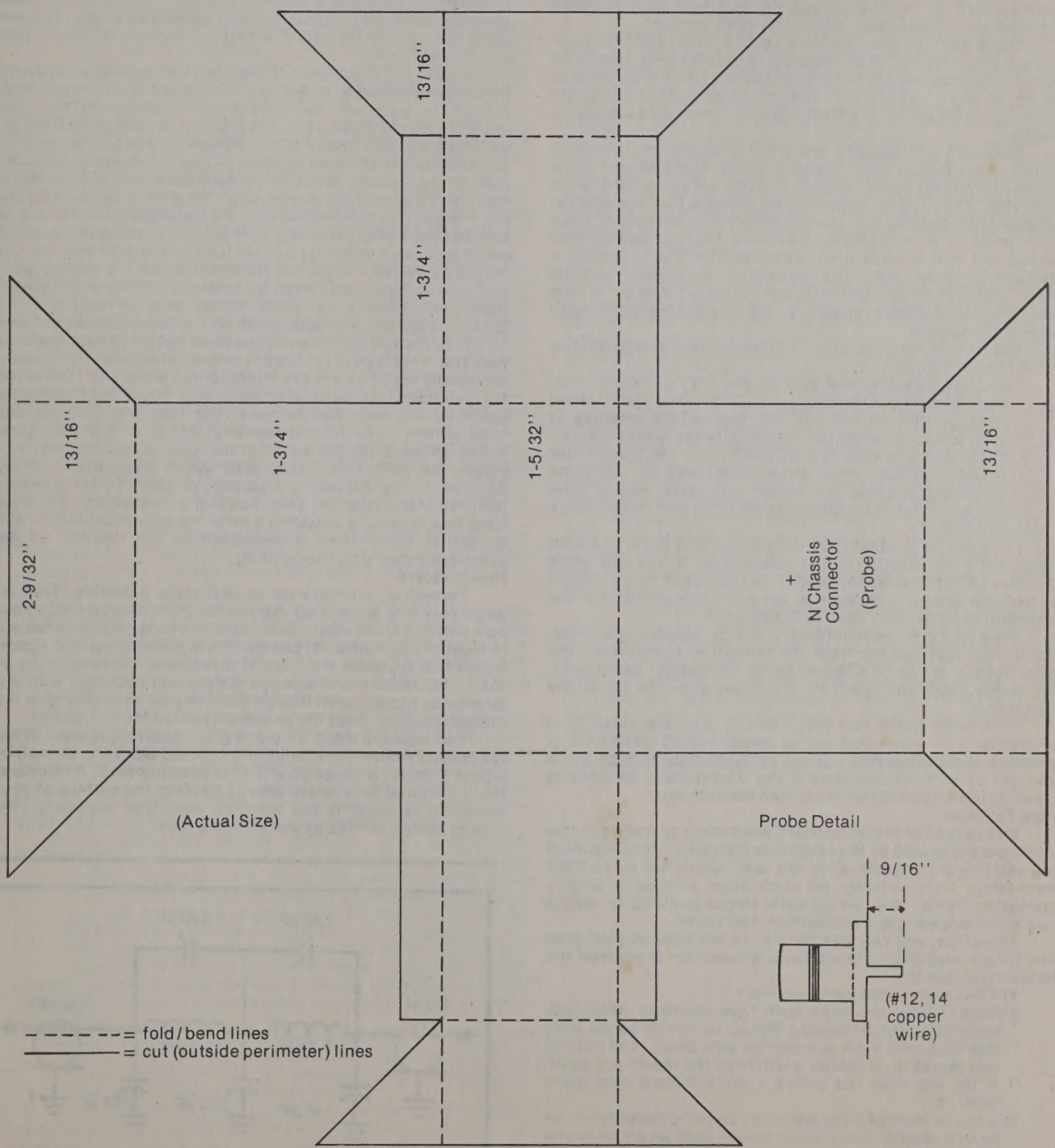
The chain of signal then is:

1)Signal is intercepted by the (Birkill Hybrid Mode) feed,
2)A probe inside of the feed couples the signal to a coupler fitting (UG 57 B/U),
3)Which in turn couples the signal into the waveguide-to-coax adapter through a second type N fitting,
4)Which now places the signal inside of the waveguide 'cavity' on the LNA.

You can count on losing .5 dB between the horn feed and the input to the LNA with this configuration. If you are not careful with your dimensions with the waveguide-to-coax adapter or your connections you could lose far more than this.

Since the primary use of the Birkill feed is to be able to polarize your system to mate or correspond to the right hand circular polarization of the Molniya or INTELSAT or GHORIZONT satellites, you have to weigh what happens if you simply elect to receive these signals with a linear polarized feed. For example, if you elect to watch one of these right hand circular birds with a linear feed you are in theory giving up 3.0 dB of signal (because your linear feed is only in-place to intercept 50% of the circular wavefront; just that portion that corresponds to your feed's linear probe). So by going to a circular feed, you could gain as much as 3.0 dB. However you can count on losing at least .5 dB in the process of getting out of your Hybrid Mode feed and into your LNA; you **may lose** 1.0 dB or even 2.0 dB in the process! All of which says that for our particular linear format feed and LNA packages, we will never gain the **full** polarization matching advantage of a full circular system. This really says **be very careful** (i.e. use good workmanship) in your waveguide-to-coax adapter and your other parts in this sytem or you may be spending time building something that will 'net' you nothing or very little when you get all done; reference a straight linear feed intercepting a circular polarized signal.

COOP'S WAVEGUIDE TO COAX ADAPTER



Use this adapter to transition from any feed without a WR/CPR 229 feed flange to the input of an LNA with such a flange. Not shown are LNA flange / adapter flange mating holes to bolt the two together. Use your LNA flange as a guide AFTER building the adapter. Accuracy of the final opening dimensions [where cavity in LNA flange mates to cavity on adapter] will determine efficiency of adapter. Make sure the adapter dimensions are uniform at both cavity [opening] end and the top [enclosed] end. (Commercial units are available from WAVELINE in Fairfield, N.J.).

TERRESTRIAL INTERFERENCE

Terrestrial interference is a little understood subject in the private TVRO field. What happens is this. The FCC assigned, long before satellites were operating, the 3.7 to 4.2 GHz frequency range for point to point (Bell, etc.) terrestrial microwave systems. These systems are in a 'mature' stage of development in most metropolitan and suburban markets although route updates and modifications continue.

These point to point services operate from tall towers or tall buildings or tall hills sending telephone and television communications over 10 to 40 mile hops at a time. A network or series of such microwave stations criss-cross the nation carrying communications from ocean to ocean and border ot border.

Most of these systems are what is known as 'thin line' routes. That means they transmit pencil-sharp beams from station to station using large horn type parabolic derivative antennas. Thus unlike broadcasting stations that transmit in all directions at once (i.e. omni directional coverage) or even VHF point to point systems that have focused beams that spread out over a wide area either side of their respective 'terrestrial boresights', the terrestrial microwave circuits come pretty close to confining their radiated energy in this frequency band to the precise heading they are transmitting to and receiving from.

Now two things happen to these pencil thin beams as they leave the transmitter:

1)**As they travel further and further** they do spread out, cutting an ever widening 'swath' over the ground. However, as they spread out (the beamwidth **enlarges** to cover more ground) the signal is being attenuated by both the distance it has traveled from the transmitter (more distance...more attenuation) **and** by the same spreading process the signal also gets weaker (the power available spreads to cover more and more square ground).

So as you get further from the station, and are in line with its antenna boresight, you get less signal. If you are some distance (20 miles away say) and off to the side of the boresight by perhaps three or five degrees, you will intercept some of the transmitted signal with your TVRO antenna.

Thus we have 'complimentary' things happening at once; the further way you are from the terrestrial transmitter, the more apt you are to be affected by its 'spreading' beam, and, the futher away you are from the transmitter the lower the signal level.

This says, quite correctly, that if you are close to a terrestrial site your chances of experiencing problems is greatest. It also says that you can be quite close to such a site and get by without problems if the transmitting antenna is pointing in some direction other than towards you.

How To Know

Virtually all of the terrestrial transmitters operating in this service are operated by the telephone company. Virtually all of the telephone company sites are well identified as to their ownership, and virtually all such sites employ a unique appearing 'horn' antenna typically atop a building or atop a four sided large angle-iron member steel tower.

Therefore, you can **look** for microwave sites in your area and simply eyeball the installations, answering for yourself the following questions:

1]If this a telephone company site?

2]Does it have the large horn type antennas (they look something like cornucopia 'horns' turned up so the wide side is up and there is a narrow side down. The narrow side tapers to its narrow width from the maximum width of the **top** side; not unlike a three dimensional giant letter 'Y')?

3)Is one or more of these antennas pointing towards my intended receive site (you can look at such an antenna and if a 'flat side' at the top where it is widest is pointing towards you - so that a line perpendicular to the flat/wide/top side would point directly at you - **then you know** you are in the general 'beam' of the antenna.)?

4)Will you, in turn, be pointing your TVRO receive antenna back towards (into the mouth of the horn antenna) the transmitting site?

If you have gotten this far and each question answers 'no' you are probably home free. We'll look at exceptions shortly.

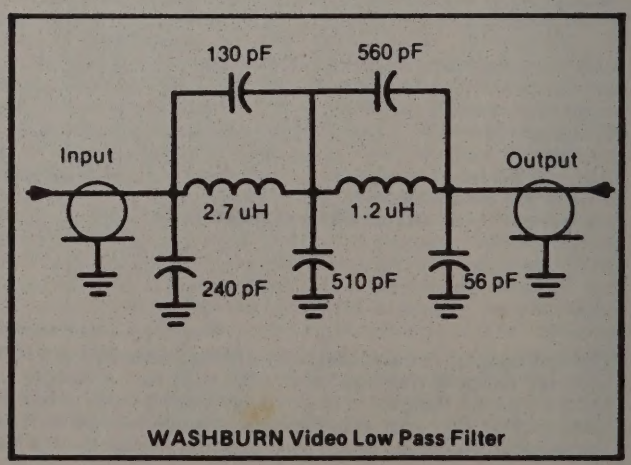
If your antenna does not point at their antenna (i.e. they are transmitting towards you) when your antenna points at the satellite, your chances for problems are slight; with one exception. If your site is 2 or more miles from their site, their antenna points off in some direction **other than at you**, you are about 99% sure of being OK. And if you are not OK? We'll talk about that shortly.

NOW - if it happens that there are tall objects around you (tall objects are hills, buildings, radio towers) which are high enough to intercept the terrestrial transmissions you can expect these tall objects to act as microwave reflectors. That is, some (small) percentage of the terrestrial transmitter energy will bounce off of these objects in unpredictable directions. Such energy usually 'scatters' in many directions at once and it may come back to you 'on a bounce'. Thus let's assume you are say 4 miles from a terrestrial site, the transmitter for that site is **behind** your TVRO antenna (i.e. it is north of you and you point south with your antenna) but yet further south of you are tall buildings. **NOW** - while the transmitter itself is behind you, and your antenna may even be shielded from the terrestrial transmission site by buildings, terrain or what have you, the tall buildings (etc.) **to your south** will act as reflector surfaces for the terrestrial beams **and send them bouncing back towards your site**. This type of problem is unpredictable but fortunately is typically found only in the metropolitan areas and then when the conditions of path alignment and building alignments specified are met. Furthermore, the reflected path signals must almost come from a building that is in line with your TVRO antenna (to the south in our example) which in turn places the reflective source also within (typically) +/- 10 degrees of the boresight heading for your TVRO antenna pointing at the satellite. This then is our 'exception'; since we have now created a situation where the actual location of the terrestrial transmitter is secondary to the location of the sub-transmitter site; the building.

How To Solve

Terrestrial interference is look-angle sensitive. That is, when your look angle is **up** there in the 20 + degree range your own antenna is not really directed at the terrestrial sources out in front of you; rather its beamwidth is pointing **up** into space. Given this situation the natural directional characteristics of the TVRO receive site antenna simply will not align with the terrestrial signals even though they may be very strong in the immediate area. Thus the antenna itself is a form of 'shield'.

You hear the word 'shield' a great deal in this area. **What is a shield?** Actually it is anything that will **block** the terrestrial signal from arriving at your TVRO antenna feed. Remember that terrestrial microwave energy striking the surface of your parabolic reflector is not harmful; only that portion of the energy which arrives at the antenna feed.



WASHBURN Video Low Pass Filter

If you can identify the angle of arrival fo the terrestrial signal, you can plan the exact placement of your TVRO antenna to create a 'shield' between the TVRO antenna and the terrestrial signal. Short of being within a few miles of the terrestrial signal source, shielding is not complicated nor need it be expensive. For example:

1)**Your house will shield you** in many situations. Simply spot the TVRO antenna so it has proper look angle clearance to the satellite, and, the house gets between your TVRO antenna and the terrestrial source.

2)**A small mound of dirt** is a shield. Some commercial installations actually dig a small hole to drop the TVRO antenna down a few feet (taking the dirt from the hole and building a mound on the side of the hole where the terrestrial signal arrives from).

3)**The antenna itself** can be shielded (a shield, as described in the STT 'Nelson Parabolic TVRO Antenna Manual) with a rim or ridge of metal that goes around the circumference ot the antenna.

4)Unattractive perhaps, but a small section of metal **'picket fencing'** can be placed like a 'snowfence' along side the TVRO antenna between the antenna and the terrestrial source.

Unless the signal is quite strong, the best approach is to plan going in that you will have someway to probe around the 'yard' at your site for the **minimum** amount of terrestrial signal on premise. One way to do this is to take your LNA and mount your horn on it. With the LNA powered up and the TVRO receiver running, simply move around the yard with the LNA and horn **in your hand**. As you move about the terrestrial signal will 'come and go' in ridges; hot spots and cold spots. You can actually make a 'plot' of your yard measuring where (relatively speaking) the terrestrial signal is strong or weak (or not present). Take all of the weak or not present locations and determine which of these still has a good (clear) shot at the satellite belt. Having done this, now convince your wife the antenna for electrical reasons has to sit squarely in front of your garage door!

With your horn + LNA you can spot the most interference free area for your antenna. Keep in mind the signal must find its way into your LNA feed horn if it is going to be a problem. It gets there one of two ways:

1)**It goes 'direct'** from the source (or a reflective secondary source) to the feed horn by-passing the dish. It may come along the side of the dish (from behind or off to the side) and into the feed horn. Or it may even strike one of your angular struts that supports your prime focus feed and then reflect into the feedhorn.

This suggests that you may be able to solve the problem by making some small changes in the feed. Sometimes you can move it in or out a quarter of an inch (closer to or further from the dish) and not change the satellite signal level more than a few tenths of a dB; at the same time you will notice the terrestrial interference may go completely away. Don't be afraid to play with the in-out adjustment on the feed!

2)The terrestrial source may be very polarization conscious. If the signal is arriving from a reflection surface, chances are it is no longer its original polarization. In this instance you can **rotate** the feed (as you do to change polarization on the FI or FII or COMSTAR satellites) slightly (5 to 20 degrees) and not lose any measureable amount of satellite signal (the feed horn is very broad when it comes to the polarization matching adjustment) but totally eliminate the off-polarization (reflected) terrestrial signal. So don't be afraid to play with the feed rotation!

3)You may only have the interference on one or a few birds. This says your dish boresight heading is finding secondary sources for the terrestrial signal only when you are directed at specific satellites.

If you will take a piece of screen wire mesh (1/8th inch wire to wire center or tighter spacing), put it into a frame that measures at least 2 feet by 2 feet, and then mount that 'portable screen shield' on a long stick (broom stick, etc.) you can walk about the site with the portable shield moving it around to see if you can find one or more spots where its placement parallel to the reflector surface or along side of the feed reduces or eliminates the interference. If you find such a spot, this is where you should erect a permanent shield of the same (or larger) size.

What It Acts Like

Terrestrial interference can be either video or data/audio modulated. Your site may be located where only a portion of the terrestrial bandwidth (the same as our satellite 3.7 to 4.2 GHz bandwidth) is actually in use. In this instance you will find interference on only certain transponders.

Video interference looks like a second set of video; sync signals, perhaps some demodulated video and even audio. Telephone or data interference can look very much like the 'picture' you see on transponder 15 on FI (which is also modulated with audio/data) or it can appear as interference on a satellite video signal, as a bad case of sparklies (noise). If you have a situation where **some of** your transponder signals are clear but others for no apparent reason are filled with sparklie noise, terrestrial telephone/data interference could be the culprit. Telephone and data interference against a video signal does not have to be 'intelligent'; it will typically look more like a noise or horizontal/wavey line 'garbage' than it will look like something 'intelligent'.

How To Test For It

The best test system is to pull a trailer mounted antenna to the projected site, set up and turn on. While it is possible that the driveway where you stopped the rig could be the only 'clean' spot in the yard where there is no interference present, the odds are that such a 'random selected site' will be just as likely to have interference as a carefully chosen spot.

If you have reason to expect there will be interference, follow the previous suggestion and take the LNA plus horn as a 'probe antenna' and do some scanning of the property **prior to** establishing a firm location for the dish. With this type of test, either using a 'scanning receiver' (such as AVCOM or Coleman dual conversion) or have someone assist you by constantly scanning back and forth across the 24 channels on a tuneable receiver as you walk around the yard. Remember you may only have a few (or even one) terrestrial 'channel' occupied or present at your site and you cannot therefore assume that the interference will be present on some randomly selected channel.

I have found the local telephone engineers assigned to maintaining the terrestrial system to be quite helpful in passing along information **on which** of their channels are active at a given site. They will usually refer to channel numbers which are different than transponder numbers so ask them to give you the **center** frequency of the channel when getting data; that you can translate to a transponder number and receiver dial position.

ABOUT THIS MANUAL

(*Mangonui, New Zealand September 1994*)

In the beginning of satellite to home television there was NO equipment produced for home use. Only equipment for commercial installations was manufactured and because of the limited size of the commercial market, production runs were small. As late as 1979 all of the commercial satellite equipment manufacturers combined did well to produce the equivalent of 250 complete receiving terminals per month.

When early pioneers in home reception demonstrated the practicality of home reception and were widely publicised for their work there was sudden demand from interested home viewers that far exceeded the ability of the existing suppliers to cope. What resulted is a classic case study in the laws of supply and demand.

Commercial terminal systems in 1979 cost upwards of US$25,000 (the original ones in 1975 were over US$100,000; each!). By 1980 an individual could locate the various pieces of a home terminal and install it him or herself for under US$4,000. By 1981 this number was below US$2,500 and the prices continued downward such that by 1985 complete (C-band) home terminals were under US$1,000 for the basic systems.

Virtually every supplier in this then-young industry was a brand new, 'start-up' company. Within North America Bob Cooper published the industry's monthly trade journal (Coop's Satellite Digest) and created a thrice-annual series of trade shows under the STT (Satellite Television Technology) banner. By early in 1984 more than 1,000,000 home dish system terminals had been produced and sold in North America;, trade shows were attracting as many as 10,000 people to show locations such as Las Vegas. An industry had been born.

This manual was one of a series (of 13) created between July 1979 and mid 1983 to assist members of this new industry to study and better understand the strange new world of satellite television systems. **Not everything in this manual remains relevant today** (1994) and you will find descriptions here that are no longer representative of present day systems. This is especially true in the antenna-mounted electronics area where early day systems employed a device called an LNA (low noise amplifier) that operated in the 3.7 to 4.2 GHz range. It amplified the weak satellite signals and sent them 'indoors' to the downconverter (located inside of the receiver) which began the process of converting the satellite microwave signals to viewable video and audio. This entire process is now replaced with an LNB/LNF (low noise block downconverter or same with antenna feed added) installed at the dish-antenna feed point.

The purpose of reprinting this 'timeless' manual is to provide you with basic information that continues to follow the same laws of physics in 1994 as were true more than ten years ago. Consider the contents here to be educational in a friendly way, reference data which is almost impossible to locate elsewhere today. Be warned however: You will not following, exactly, very many of the procedures described here in creating your own 1994-era home satellite dish systems.

Additional notes: When the 'home satellite revolution' started in 1979, Bob Cooper lived in the US state of Oklahoma. By 1980 the family completed a long-in-planning move to the British territory of the Turks & Caicos Islands in the northern Caribbean. Reference to Oklahoma, and the Turks and Caicos Islands, are thus explained. Addresses given here for suppliers and other enthusiasts are probably no longer valid; if you require additional information contact Bob Cooper in Mangonui (FAX: 64-(0)9-406-1083).